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ABSTRACT

This three-volume student text is designed for use by Air Force personnel enrolled in a self-study extension course for aircraft electrical systems specialists. Covered in the individual volumes are career field fundamentals, electrical systems and test equipment, and aircraft control and warning systems. Each volume in the set contains a series of lessons, exercises at the end of each lesson, a bibliography, and answers to the exercises. A change supplement to the third volume, containing page revisions and pen and ink changes, is also provided. (MN)

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AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST

(AFSC 42350)

EXTENSION COURSE INSTITUTE

AIR TRAINING COMMAND

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LIST OF CHANGES

COURSE NO.
42350

EFFECTIVE DATE OF SHIPPING LIST
21 Sep 84

CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.

1. CHANGES FOR THE TEXT: VOLUME 1

a. Page 16, col 2, line 9 from bottom: Change "1977" to "1983."

b. Page 21, col 1, lines 14 and 15 from bottom: Delete "Let's say you . . . is not on" and replace with "The next higher."

c. Page 70, col 1, line 18 from bottom: Change "recommended" to "mandatory."

d. Page 80, Exercises (077)-6: Delete.

e. Page 106. answer 057-8: Delete. Answer 057-9: Change "057-9" to "057-8." Answer 057-10: Change "057-10" to "057-9."

f. Page 108, answer 086-5: After "086-5." add ".5 volt."

2. CHANGES FOR THE TEXT: VOLUME 2

a. Page 4, col 2, last line: Change "+" to "=."

b. Page 5, col 1, line 4: Change "=" to "+."

c. Page 6, col 2, line 20: Delete "permanent" and "is." Line 21: Change period to a comma and add "thus reducing its usefulness as a permanent magnet."

d. Page 14, col 2, line 32: Change "high-power" to "high power."

e. Page 25, col 1, line 15: Change "voltge" to "voltage."

f. Page 34, col 2. line 28: Place parentheses around the plus sign "(+)."

g. Page 88, col 1, lines 11-14 from bottom: Delete "Note that both . . . only when de-energized."

3. CHANGES FOR THE TEXT: VOLUME 3

a. Page 10, col 2, lines 12-13: Delete "The system selected . . . the F-4 aircraft."

b. Page 26, col 1, line 27: Change "C" to "C1."

c. Page 56, col 1, lines 20 and 18 from bottom: Change "fact" to "face."

d. Page 58, col 2, line 19 from bottom: Change "shots" to "shorts."

e. Page 71, col 2, lines 13-15: Delete "Two of these . . . in Volume 2."

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CDC 42350

AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST

(AFSC 42350)

Volume 1

Career Field Fundamentals

Extension Course Institute

Air Training Command

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Preface

THIS CAREER Development Course (CDC) is designed to help you in your upgrade training. It contains subject information and task knowledge you need to advance to the 5 skill level. This course is in three volumes. Volume 1 pertains to career field fundamentals. Volume 2 covers test equipment and electrical systems. It deals with AC and DC theory and circuits; AC and DC meters and testers; AC and DC generators; aircraft power systems; and motors. We also discuss the use of diagrams and schematics. The last volume discusses aircraft control and warning systems. The landing gear and related systems, flight control systems, starter systems, fuel systems, aircraft warning systems, lighting systems, and nesa glass systems are the major topics in Volume 3.

This first volume is divided into five chapters. In Chapter 1, you study areas relating to maintenance management, career progression, graduate evaluation, and security programs. Chapter 2 covers Air Force publications including technical orders, supply discipline, the maintenance data collection system, and aircraft forms. In Chapter 3, we discuss flight-line safety, ground safety, and foreign-object damage. Chapter 4 covers handtools and electrical hardware. Common hardware, safety devices, control and protection devices, electrical connectors, wiring, tools you use, soldering, inspections, and the composite tool-kit program are all taught here. Chapter 5 discusses batteries, servicing equipment for batteries, and battery shops in general.

Code numbers appearing on figures are for preparing agency identification only.

The inclusion of names of any specific commercial product, commodity, or service in this publication is for information purposes only and does not imply indorsement by the Air Force.

Call the author by AUTOVON (826–2221) between 0600 and 1500, Monday through Friday, to get an immediate response to *subject matter* questions which come up while you are studying this course. Or you may write the author at 3370 TCHTG/TTGU–E, ATTN: MSgt Leslie R. Savage, Chanute AFB IL 61868. Sending subject matter questions to ECI only slows the response time. You should also tell the author about subject matter and technical errors (except minor printing errors) that you find in the text, the volume review exercises, or the course examination. This will help the author to keep up with changes that must be made when the course is revised.

Consult your education officer, training officer, or NCO if you have questions on course enrollment or administration, Your Key to a Successful Course, and irregularities (possible scoring errors, printing errors, etc.) on the volume review exercises and course examination. Send questions these people can't answer to ECI, Gunter AFS AL 36118, on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of October 1982.

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NOTE: This course teaches through numbered lesson segments, each containing a behavioral objective, text, and exercises. The objective sets your learning goal. The text gives you the information you need to reach that goal, and the exercises let you check your achievement. When you complete each segment, see whether your answers match those in the back of the volume. If your response to an exercise is incorrect, review the objective and its text.

Maintenance Management and Career Progression

THE AIR FORCE is one of the largest organizations in the world. Just as with any business, however large or small, it must be organized. In a military unit, the organization is determined by the mission that the unit is to accomplish. Accordingly, maintenance units, such as the one you are working in, are organized and equipped to perform only certain levels of maintenance.

No matter what type organization you are assigned to, that organization can be made better by having everyone in it do their best and encouraging them to take pride in a job well done. As an aircraft electrical specialist, you are an important part of the maintenance organization. In this chapter, you learn how the maintenance organization is set up and how you can progress in your career field.

1-1. Responsibilities of the Deputy Commander for Maintenance

AFR 66-1, Maintenance Management, provides guidance and procedures for documenting activities of maintenance and inspection systems. The organizational structure, as outlined in AFR 66-1, is designed to be flexible. It must be flexible to meet the varying needs of the Air Force. The efficient operation of organizational maintenance management is the responsibility of the Deputy Commander for Maintenance and staff.

001. List the functions that are a responsibility of the DCM and name the directive that lists these functions.

Deputy Commander for Maintenance (DCM). The Deputy Commander for Maintenance manages the assigned maintenance complex. Responsibilities and functions that are assigned and pertain strictly to the DCM are found in AFR 66-1. Included in the DCM's responsibilities are planning, scheduling, controlling, and directing the use of all maintenance resources to meet mission requirements of the organization. To discharge responsibilities, the DCM requires firm discipline and a strong quality control program that meets standards set by technical data and other directives. DCM staff agencies are covered in the next section.

Exercises (001):

1. List the functions of the DCM.

2. What Air Force regulation lists the functions of the DCM?

002. Differentiate among the duties of the DCM's staff agencies.

Deputy Commander for Maintenance Staff. The job as DCM is all-encompassing and very challenging; therefore, it is necessary for the DCM to solicit help from the staff. The staff is divided into several agencies, and each agency is responsible directly to the DCM for its own function.

Maintenance Control. Maintenance Control is responsible for directing maintenance, authorizing the expenditure of resources, and controlling actions required to support the mission. Maintenance Control manages the full cycle of production by planning, scheduling, directing, and controlling all maintenance on primary mission, mission support, and transient aircraft.

Job Control. Job Control directs and controls the use of maintenance resources. This activity controls all maintenance and services on aerospace vehicles and related support equipment by monitoring their status and directing maintenance actions. Job Control also implements the maintenance plan and schedule the accomplishment of unscheduled maintenance requirements. When a unit operates or maintains equipment on a 24-hour day, Job Control is manned accordingly.

Plans and Scheduling, and Documentation. Plans and Scheduling and Documentation completes maintenance data for the DCM. This section also briefs the DCM on any changes required to meet mission requirements and records and maintains all time compliance technical orders (TCTOs).

Materiel Control. Materiel Control section provides coordination between maintenance and supply for needed parts and equipment. When Maintenance Control requires equipment, it is often needed quickly. Materiel Control makes every effort to help locate the property in Base Supply. If Materiel Control is unable to locate needed parts, it may authorize the removal of the component from another aircraft that is out of commission for major repair. This action (cannibalization) is authorized only in emergencies.

Quality Control. Quality Control insures that quality maintenance is the rule and not the exception. Personnel assigned to this section should be the most qualified technicians that the unit has to offer. They inspect and evaluate maintenance and work closely with the supervisors. Quality Control assists in maintaining good safety programs in flight operations and in maintenance. Quality Control also maintains the master library which contains technical orders pertinent to mission accomplishment.

Administration. This section has the administrative responsibility for the DCM. It must establish, sort, file, and maintain all correspondence generated by the DCM and staff. Administration is also the control point for distribution. It assists other agencies within the maintenance complex as required.

Training Management. The Training Management is responsible to the DCM for insuring that all personnel are highly trained. As training requirements are discovered, Training Management must make every effort to arrange the necessary training. It also administers required tests to personnel to insure proficiency.

Exercises (002):

1. Name the staff section that monitors the TCTO program.

2. Which staff section maintains the master TO library?

3. What is the main function of Training Management?

4. What is the main function of Administration?

1-2. Career Progression

The aircraft systems involved in maintenance organizations are increasing in complexity with each aircraft delivered to the Air Force. To maintain these advanced systems, a large number of specialties of various skill levels are required. You will find that your entire Air Force career progresses from skill level to skill level as you increase in experience and proficiency. In order for you to understand this progression, you need knowledge of the personnel classification system, specialty codes, skill levels, and upgrading.

003. Specify the steps for progression within the 423X0 career field and the four areas of the armed services aptitude test.

Initial Airman Classification. The essential link between the public and the Air Force is the Air Force recruiter-salesman, one of the many dedicated career noncommissioned officers who represent the Air Force in communities throughout the United States. Through the use of radio, television, news periodicals, personal appearances at high schools and civic organizations, and personal interviews at the recruiting office, the recruiter explains to prospective applicants the various career opportunities available to Air Force officers and enlisted personnel.

Testing. Applicants desiring to enlist are given the Armed Services Vocational Aptitude Battery (ASVAB) at the recruiting office. The results determine their eligibility for enlistment in one of four areas—administrative, general, mechanical, and electronics. Qualified applicants are guaranteed a specific job or a job assignment within the area of their choice; that is, if they score a sufficient percentage in that area to meet the minimum score. While the recruiter completes the applicant's initial processing, the applicant is given a physical examination and the Armed Forces Qualification Test (AFQT). This test determines the enlistee's qualifications for enlistment. If all processing and examinations are favorable, the applicant is given a firm date for enlistment at the Armed Forces Examination and Entrance Station (AFEES) and transportation to Lackland AFB for basic military training.

Basic military training. Initial orientation and primary processing of no prior service (NPS) airmen are accomplished at the Air Force Military Training Center. This is where training begins. Drill, military studies, marksmanship practice, and physical fitness and conditioning are part of the introduction to military life. Every person who enters the Air Force should become physically fit, disciplined, personally adjusted, and knowledgeable of the role of the Air Force in peace and war. It is hoped and intended that the enlistee becomes an all-around better citizen as a result of this basic training. Concurrently, airmen are classified into the Air Force specialty (AFS) in which they will train and serve.

Classification. The process of classification begins immediately upon the enlistee's arrival for basic training. Personal classification data is collected during the first few days after arrival. The Airmen receive career guidance, complete a biographical data record reflecting their prior education and work experience, receive counseling on the opportunities for special assignments, and determine their choices of available career fields. When additional testing, security processing, and physical examinations are completed, data collected is consolidated and entered into the computer. Meanwhile, the availability of career fields, technical training requirements, and types of training are also fed into the computer. The computer identifies the specialties in which individuals are best qualified; it also classifies them to the job in which they are best qualified. Subsequent computer programs produce, at the completion of basic military training, mechanized special orders assigning the basic airmen to a technical training school or to a directed duty assignment DDA); (that is, the assignment of basic military training graduates to the field instead of technical school. Recruiters operating in a "zero draft" environment often enlist personnel into selected specialties under guaranteed job selection options, thus bypassing many classification procedures during basic military training.

Technical school or DDA. After graduation from basic military training, the Air Force decides which training route best suits your initial career training requirements. You were sent to the Basic Aircraft Electrical Systems Specialist Course, 3ABR42330. The basic course is desirable for progression in this career field.

Exercises (003):

1. List the four main steps involved in initial classification.

2. The ASVAB measures what four aptitude areas?

3. When are NPS airmen classified into the AFS in which they will train?

004. Define classification system terms.

Career Development. Career development in the Air Force focuses on providing the most capable airmen with the opportunity to increase their job competence through training and work experiences. By doing this, the Air Force also develops and maintains personnel for higher level supervisory and managerial positions. Before further describing how the Air Force increases the skills and knowledges of its people, we discuss two basic concepts, Air Force specialties (AFSs) and skill levels.

AFSs and career fields. The Air Force policy is to develop each individual's skill and knowledge to the fullest extent. The Air Force classification system is designed to carry out this policy. The classification system categorizes various jobs and positions into AFSs. Related AFSs are then grouped into broad career fields. A career field is a group of positions which require common qualifications. An AFS is identified by an AFS title and code, called the Air Force specialty code (AFSC). The AFSC indicates not only the technical specialty of the individual but also the person's level of proficiency.

Specialty description. AFR 39-1, Airman Classification Regulation, contains specialty descriptions for AFSs. If you were to look at several of these descriptions in AFR 39-1, you would find that they all contain the same type of information. The information included and what it means to you is given in brief form below:

- The AFSC for your career field is 42330/42350/42370.
- AFS Title—yours is "Aircraft Electrical Systems Specialist."
- Summary of Specialty—brief description of AFS.
- Duties and Responsibilities—what personnel in the AFS do.
- Specialty Qualifications—requirements for knowledge, education, experience, training, or other qualifications for AFS.
- Specialty Data—restrictions on grade spread; Department of Defense (DOD) and Dictionary of Occupational Titles (DOT) related jobs.

Air Force specialty codes. AFSCs have a definite meaning. Take your AFSC, 42350, for example. Let's examine what it means to you and others who read it. Refer to figure 1-1. The first two digits, 42, identify a career field. There are approximately 50 career fields in the Air Force airman classification system. The 42 career field is the Aircraft Systems Maintenance Career Field. This is a large grouping of specialties which are all related to aircraft accessory maintenance.

The third digit of your AFSC, 3, identifies your career field subdivision. The Aircraft Systems Maintenance Career Field is divided into several subdivisions such as: (1) 423X0, Aircraft Electrical Systems; (2) 423X1, Aircraft Environmental Systems; (3) 423X2, Aircrew Egress Systems; (4) 423X3, Aircraft Fuel Systems; (5) 423X4, Aircraft Pneudraulic Systems; and (6) 423X5, Aerospace Ground Equipment. Your AFSC begins with 423. This designates that you are in the Aircraft Accessories Systems subdivision under the Aircraft Systems Maintenance Career Field.

The fourth digit identifies the skill level. The Air Force uses skill levels 3, 5, 7, and 9 to show the point of progression in various career field ladders. A career field ladder is a vertical (up and down) arrangement of AFSCs in a career field. Near the bottom of the career field ladder is the 42330 AFSC. This refers to an Apprentice Aircraft Electrical Systems Specialist which is a semiskilled position. The next higher progression is Aircraft Electrical Systems Specialist, 42350, which is a skilled position. Next is the 42370, or the Aircraft Electrical Systems Technician, which is an advanced position.

The fifth or last digit of your AFSC, 0, identifies the specific Air Force specialty within the career field subdivision. The last digit (0) designates the specific AFSC of the Aircraft Electrical Systems Specialist.

Your skill level affects your promotion eligibility. Your progression to a higher skill level allows you to become eligible for the rank consistent with that skill proficiency.

Types of AFSCs. Every airman in the Air Force carries several types of AFSCs. First, you have an awarded AFSC which you are given following certification of your ability to perform the duties of an Air Force specialty at a specified skill level. This is the AFSC you were awarded upon completion of the basic Aircraft Electrical Course. When you complete upgrade training for the 5 level, your awarded AFSC changes from 42330 to 42350.

Primary AFSC. You also have a primary AFSC which is the awarded AFSC in which you are most qualified. Unless you have worked in some other AFSC and cross trained into aircraft electrical, your awarded and your primary AFSCs will be the same.

Control AFSC. Your control AFSC is the AFSC the Air Force uses to control your assignments from base to base. It also assists the Air Force in identifying and controlling training requirements. After you complete technical training, your awarded, your primary, and your control AFSCs are normally the same, 42330. Once you reach the rank of E-4, your control AFSC changes to 42350, whether you have completed on-the-job training (OJT) or not. After you reach the rank of E-6, your control AFSC changes to 42370.

42	CAREER FIELD	AIRCRAFT SYSTEMS MAINTENANCE
3	CAREER FIELD SUBDIVISION	AIRCRAFT ACCESSORY SYSTEMS
5	SKILL LEVEL	SKILLED LEVEL
0	SPECIFIC AFS	ELECTRICAL
42350	COMPLETE CODE OF AN AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST	

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Figure 1-1. Coding an Air Force specialty.

Duty AFSC. Lastly, you have a duty AFSC. This AFSC identifies the skill level of the position to which you are assigned on your organization's unit detail listing (UDL). The shop to which you are assigned may not have any positions authorized for your present AFSC, 42330. If not, you will probably be assigned a duty AFSC of 42350, even though you do not hold it as your primary AFSC. The duty AFSC denotes the duty requirements of the individual assigned to it. Your shop chief normally is assigned to a 42370 position. This duty AFSC will be assigned to the highest ranking individual in the shop. As you can see, the duty AFSC is used to show the level of proficiency required of the individual holding each duty position.

Exercises (004):

1. Define the following classification terms:

   a. Career field.

   b. AFSC.

   c. Specialty description.

   d. Awarded AFSC.

   e. Primary AFSC.

   f. Control AFSC.

   g. Duty AFSC.

2. Identify the meaning of the 42350 AFSC by digit designators.

   a. 42.

b. 3
c. 5
d. 0

005. Distinguish among the duties of the various skill levels in the aircraft electrical systems career field ladder.

Duties of AFSs. The duties or tasks you do at work depend on a lot of factors. Your rank, skill level, experience, and the shop you are in all have a direct bearing on the work you do.

The 3 skill level. Your duties and responsibilities as a 3 skill level are varied, yet limited, to protect you and the maintenance activity you are assigned to. As a newly assigned 3 skill level, you studied many hours toward advancement within the career ladder and were closely supervised during training on the job or at "tech school." Your responsibilities were limited but increased gradually as you gained experience. As a 3 skill level, you did most of your work under the direct supervision of your OJT trainer or instructors.

The 5 skill level. The duties and responsibilities of the 5 skill level are much the same as those of the 3-skill level, with a few exceptions. The biggest difference is in the amount of supervision required. As a 5 skill level, you must be competent in areas of maintenance and inspection on various electrical systems. The level of competency is determined by the coding in the specialty training standard (STS) or job proficiency guide (JPG). The 5 skill level specialist can also function as an OJT trainer for 3-skill-level trainees. Because you may perform in this position, the capability to supervise personnel is also a requirement for obtaining the 5 skill level. Another area of increased responsibility is your financial responsibility for equipment. The ability to work as a specialist with limited supervision indicates that you are capable of more responsibility for the equipment you use.

The 7 skill level. A 7-skill-level aircraft electrical technician analyzes problem areas of jobs and determines a reasonable solution to rectify them. Although a 7 skill level must have the ability to perform 5-skill-level work, he or she is more of a manager and supervisor. A 7 skill level's responsibilities include the following:

a. Plan work loads and schedule work assignments.
b. Improve work methods.
c. Establish procedures.
d. Prepare and analyze reports.
e. Determine personnel requirements.
f. Develop organizational structures.
g. Establish work standards and priorities.
h. Coordinate and determine individual and group training requirements.

Exercises (005):

1. Cite the basic difference in the responsibilities for the 3 and 5 skill levels.

2. Match the duties listed in column A to the skill levels listed in column B.

Column A	*Column B*
___ (1) Acts as an OJT trainer for newly assigned workers.	a. 3 skill level.
___ (2) Deterines individual and group training needs.	b. 5 skill level.
___ (3) Plans work loads and schedules work assignments.	c. 7 skill level.
___ (4) Works under direct supervision of a trainer.	

006. Identify duties that require cross-utilization training (CUT) and define CUT.

Cross-Utilization Training (CUT). CUT is training which qualifies a person to do tasks that are not part of the primary AFSC. CUT consists of practical training and may also include training conducted by the field training detachment. Cross-utilization training for you may include such tasks as:

a. Jacking aircraft.
b. Towing aircraft.
c. Washing aircraft.
d. Troubleshooting radio, radar, or environmental systems.
e. Repairing components in other aircraft systems.

This is not a complete list of tasks; what you are trained to do depends on the organization to which you are assigned. CUT should not interfere with the upgrade of 3 skill levels.

Exercises (006):

1. What is the simple definition of CUT?

2. Place an X beside those duties that would require CUT.

___ a. Troubleshooting a landing light.
___ b. Washing an aircraft.
___ c. Checking the generator system.
___ d. Repairing a VHF radio component.

007. Specify the purposes of and the methods of conducting the Graduate Evaluation Program.

Graduate Evaluation ProGram. The graduate Evaluation Program is used to aid the quality control of formal and career development courses. It serves as a source of information to determine the ability of recent graduates to perform their assigned tasks to the level of proficiency specified in the applicable STS.

It also determines the extent to which assigned skills are used and the knowledge that is attained or retained by recent graduates. The evaluation gives insight into the need to revise the approved training standard, resident courses, or career development courses, and to improve training effectiveness and responsiveness to the requirements of the using commands. The evaluation of graduates may be conducted by any one of these methods: (1) field evaluation visits, (2) the CDC training questionnaire, (3) the direct correspondence questionnaires, or (4) the Training Quality Report.

Field evaluation. Personnel from training activities visit bases within 6 months after the graduates are assigned—within 12 months if graduates are Air Force Reserve (AFRes) or Air National Guard (ANG) units. They obtain evaluation data by discussion with the graduates, with their immediate supervisors, and with others having knowledge of the graduates' performance. The applicable training standard is used as the reference to evaluate each graduate's frequency of use and the ability to perform the task for which he has been trained.

Direct correspondence questionnaire. The questionnaires for formal course graduates are sent to recent graduates and their supervisors. They are mailed by the training activities to graduate-receiving units within 6 months after graduation (within 24 months for personnel not on extended active duty and who are assigned to AFRes and ANG units). The questions asked pertain to graduate qualification in terms of the skills and proficiency levels reflected in the approved training standard.

When a sufficient number of responses have been received by the originator, a training evaluation report is prepared by the evaluation division of the technical training center concerned. Course personnel immediately respond to this report resulting in the change(s) necessary to adapt that training to total Air Force needs.

Unfortunately, it is not economically feasible to train everyone to perform all tasks encountered in all job assignments. Formal training time must be slanted toward satisfying the common needs Air Force wide. Those additional job performance requirements that are peculiar to an individual's job assignment must be acquired through on-the-job-training.

CDC trainee questionnaire. A sampling of CDC enrollees complete the CDC trainee questionnaire when they take course examinations. The CDC testing officials collect the forms and mail them to ATC training centers within 1 week of administration of the test. At the training centers, the forms are analyzed much the same as the formal course graduate direct correspondence questionnaires and, usually, the results are the same. If responses identify problem areas in the CDC, the training activities must conduct followup evaluation projects to determine the actions required to resolve them.

AF Form 1284, Training Quality Report. With this form, the immediate supervisor may inform the training activity directly when a graduate does not meet the proficiency or knowledge specified for any task listed in the approved STS. As an example, if the immediate supervisor should observe that a graduate from a particular technical training course doesn't know the difference between a hammer and a screwdriver, the supervisor would check the STS to determine to what level the graduate was trained. If the conclusion is that the graduate had not achieved this level, the supervisor should submit an AF Form 1284.

Exercises (007):

1. What is the objective of the USAF Graduate Evaluation Program?

2. List four ways you may be required by ATC to participate in the Graduate Evaluation Program.

3. Name the title and form number of the report that is submitted when the supervisor feels undertraining or overtraining has occurred.

008. Associate the Operational Security (OPSEC) Program with information, communication, and physical security programs.

Security Programs. Security is the sum total of every individual's adherence to and compliance with sound security practices. Adequate security can be obtained only by effective direction from supervisors, coupled with alert performance of duty by each member of the Air Force.

Information Security. This program provides a categorizing system for information according to its importance (Top Secret, Secret, Confidential) and indicates that unclassified information, too, can be of value to the enemy (bits and pieces of information may be harmless by themselves but, when compiled, this information could reveal facts about our plans and operations. The Information Security Program requires that everyone in the Air Force be informed of individual responsibility for protecting classified and unclassified information.

Communications Security. This program is designed to deny unauthorized persons information of intelligence value that they may get through any communication media. It particularly discourages talking about such information over the telephone or when unauthorized persons are present. The proper transmittal and storage of this matter is also included in this program.

Physical Security. This program deals with the area of security interest in terms of threats of physical damage to Air Force operational resources. These resources are primarily in the aircraft or weapon systems, command post and facilities, and weapons (nuclear and conventional). Security Police are not the only ones responsible in this area. Every member of the Air Force must shoulder his or her share of security responsibility.

As you can see, these programs are related to the OPSEC Program. Although they are different programs with different intermediate objectives, their ultimate objective is to provide an all-encompassing security system.

Exercises (008):

1. Airman Smith works downtown when she is "off duty." One day she called her civilian employer on the

office phone. While she was on the phone, other airmen in the office were discussing information on the type of cold-weather clothing to take with them on an upcoming classified military operation. Name the security program(s) violated.

2. Sergeant Walk is on a weapons load team. He knows a sergeant on another load team who is a part-time bartender at the NCO Club. At the club, Sergeant Walk tells the sergeant about the bombs that his team loaded on the aircraft that flew that morning. They are a new type of bomb that would not explode on impact but would bury themselves in the ground. They were timed to go off 24 hours later. There are several club employees within hearing distance. Name the security programs violated and explain your answers.

009. State OPSEC vulnerabilities.

Applying OPSEC. The Air Force OPSEC Program is centered around the activities of each major command. This arrangement is sound because of the difference in operational missions. However, it is often the day-to-day operations within an operating unit that result in an OPSEC weakness. Shortcuts and time savers at the working level have proven to be a source of intelligence to the enemy in the past.

There are many types of information regarding an operation that should be protected. Examples of such types of information are:

a. Objectives of the operation.
b. Operation time and location.
c. Friendly and enemy forces involved.
d. Known or suspected limitations.
e. Methods of employment.
f. Results of the operation.
g. Sources of intelligence data.

Objectives of the operation may include information about the testing of a new radar or weapon system on the aircraft. The operation time and location could be made vulnerable by a casual remark that you are going to the desert for the weekend. These examples reflect two of the most common types of OPSEC vulnerabilities.

Exercises (009):

1. What is a proven source of intelligence to the enemy?

2. List the two most common types of information that are OPSEC vulnerabilities.

010. Identify sources of unclassified data procedures.

OPSEC Weaknesses. The success or failure of combat operations is contingent upon the element of surprise. Before an operation can be kicked off, personnel must be assembled, equipment and means of transportation amassed, and numerous other activities completed. Usually, definite patterns of behavior or action are followed. These patterns can become alerting signs to enemy intelligence collectors. Attempts to gain information about planned operations is not an innovation; it is an age-old practice. A forewarning may provide time to institute countermeasures that reduce or negate the advantages of surprise.

The need for overall security is not limited to major combat operations. Foreknowledge of any combat operation could enable an enemy to disperse, go into hiding, or change offensive tactics. Air Force experience and studies have shown how certain knowledge about operations may be made available to an enemy without violating any security rules. For example, the posting of flight schedules where foreign nationals could see them, the establishment of procedures such as standard flight patterns, or other "normal" procedures can enable the enemy to predict important aspects of a planned operation. Facts about specific activities can also be revealed in unclassified communications. The elimination of these information leaks helps to protect the surprise element in combat operations. To assist in eliminating potential OPSEC weaknesses, this list of indicators is furnished:

a. Operational Indicators.

(1) Serotyped sequences of events.

(2) Coordination with other agencies that do not have proper safeguards for information.

(3) Stereotyped patterns of flight activity.

(4) Submission of unclassified reports at specific intervals.

b. Procedural Indicators.

(1) Public information releases.

(2) The posting and/or transmission of orders or flight plans in unsecure areas.

(3) The posting of duty rosters, transportation schedules, dining hall schedules, etc., in unsecure areas.

(4) Distinctive emblems or paintings on vehicles, buildings, or aircraft.

(5) Markings on supplies that indicate the location or starting date of the operations; that is, nicknames, delivery deadlines, etc.

(6) Logistic buildup or positioning of support materials.

(7) Special briefings, meetings, or religious services.

(8) The use of nicknames, since a nickname provides an easily recognizable "flag" for actions associated with a particular operation.

(9) Testing portions of the plan.

c. Communications Indicators.

(1) Plain-language communications associated with a planned operation.

(2) Use of unchanging call signs and/or radio frequencies.

(3) Stereotyped message characteristics.

(4) Significant increase or decrease in message traffic volume.

(5) Activities of new communications facilities.

Exercises (010):

1. Place a check mark beside the sources of unclassified data procedures.

____ a. Using a nickname with all activities involved in an operation.

____ b. Posting the chow hall menu and schedule on the bulletin board. .ti -199u ____ c. Putting all supply personnel on 12-hour shifts.

____ d. Notifying the motor pool that all of the refueling trucks must be "in commission" by a certain date.

011. Cite OPSEC vulnerabilities in the 423X0 career field.

OPSEC in Practice. The main objective of OPSEC is to provide necessary security to our operations during the planning, execution, and after-action phases. One of the most important lessons to be learned is the ease with which an actual or potential enemy can obtain foreknowledge of our operations. Foreknowledge gives the enemy an advantage that had been ours.

Standardized practices reveal information concerning the what and how of actions to take place. The tendency to "get the word out" to everyone interested in the operation detracts from the basic security principle of "need to know." The individual at the working level should become aware of the impact or value that intelligence information and activities have to an actual or potential enemy. It is quite easy to see this in a combat operations situation. What about peacetime operations and projects? To answer a question with a question, "Why make any opportunity available?"

In the shop where you work, bits of information may be passed around concerning an operation. A successful operation requires that you be given enough information so that you can make preparations. There may be shifts to change, parts to order, and equipment to pack. An operation may require that you go TDY. You may need someplace to store your car. You may need someone to look after your family. You may have to pay some bills. Nevertheless, information concerning this operation should not be revealed to unauthorized persons, including your wife or husband, or mother.

In another situation, operational readiness inspections (ORIs) reveal capabilities of organizations that could be of significance to the enemy. Knowing the facts, you must be careful not to discuss them with others. A careless act, just plain ignorance, or a few words spoken in an unguarded moment may turn you into an involuntary espionage agent. Each of us must be conscious of security responsibilities daily. You, as an individual, are a key element in the effectiveness of all of our security programs.

Exercises (011):

1. Your shop is notified to ship a special tester that is used on the newest Air Force fighter. The tester is to be sent to Greece, where it will remain for 89 days. What should you do with this information?

2. Several men in your shop have experience on reconnaissance-type aircraft. They are all notified that they are going TDY to Korea in July. What should you do with this information?

Publications, Forms, and Supply

AS AN AIRCRAFT electrical systems specialist, you may feel at times that supply, use of publications, maintenance management forms, and procedures are an unimportant part of your job. However, the accuracy of your performance in these areas is very important to the Air Force and you. Almost every job to which you are assigned will involve the filling out of maintenance forms, the ordering of parts, and the use of publications. By achieving the learning objectives that follow, you will acquire knowledge that will aid you in this area of your duties.

2-1. Air Force Publications

Have you ever started to do a job no any idea of how to do it, where to start, or what you need to complete it? This is where Air Force publications come in. They save you time and energy. Why should you stumble and fumble making up procedures that others have already worked out?

There are many types of Air Force publications. It is to your advantage to learn about these publications and how to use them. During your military service these publications will be a great help to you. As a specialist, you will use technical order publications more often than you use standard publications (regulations and manuals).

Even so, you should become acquainted with the various types of Air Force publications. You should also become adept in the use of indexes and other basic references. This will help you locate the information needed to complete your work. In this chapter, we first examine the types of Air Force standard publications. Then we'll proceed toward your more immediate concern—a a survey of the Air Force technical order system.

012. Distinguish among the types of Air Force publications.

Air Force Publications. Air Force publications may be divided into two general classes: departmental and field. Departmental publications are issued by (or for) Headquarters USAF. They apply to the entire Department of the Air Force. Field publications are issued at major command level or below for use within the issuing organizations.

Another way that Air Force publications can be divided is (1) standard publications and (2) specialized, miscellaneous, and other publications. We will not discuss the latter, but will use this division in organizing our discussion of official publications.

Standard Publications. We begin our discussion with standard departmental publications. These are most frequently used throughout the Air Force. They are used to announce policies, assign responsibilities, prescribe procedures, direct actions, and inform or motivate personnel. Let's look at the following standard publications and their specific uses.

Air Force regulations (AFRs). Air Force regulations are the most numerous of all Air Force standard publications. They contain directive and policy material and assign responsibilities; they also may include brief procedural details when necessary. Regulations are usually permanent in nature. When it is known that a regulation will cease on a specific date, the expiration date is included.

Air Force manuals (AFMs). Manuals give detailed instructions (procedures and techniques) that tell personnel how to perform their duties. The contents of a manual may be general and deal with principles or doctrines. A manual may direct the step-by-step performance of a specific task. It may include policies or assign responsibilites when this is not covered in another publication. Manuals also differ from regulations in that they contain a foreword page. They have a contents page that lists chapter titles, main subdivision of chapters, and corresponding page numbers.

Air Force pamphlets (AFPs). Pamphlets usually contain information of a nondirective nature. They are written in an informal style and are usually published in brochure or booklet form. They are permanent in nature, but an expiration clause may be included if it is desired.

Operating instructions. Operations instructions are similar to regulations but apply only within the issuing headquarters. These instructions are designated headquarters operating instructions (HOIs), branch operating instructions (BOIs), etc. Operating instructions (OIs) must comply with existing higher level directives and be updated accordingly.

Supplements. Supplements are used by lower headquarters to implement, amplify, interpret, or clarify a higher level publication. A supplement does not alter or change the intent of the basic publication. A lower headquarters can supplement a basic publication, but they cannot make additions to the supplement of a higher headquarters. Supplements are filed behind the basic publication or behind the supplement of the next higher headquarters.

Exercises (012):

1. The Air Force issues both standard and specialized publications. Which of these is used normally to announce policies, assign responsibilities, prescribe procedures, and direct actions?

2. Cite the difference between the contents of an Air Force regulation and those of an Air Force manual.

3. Which Air Force publication is written in an informal style?

4. Which regulation applies only within the issuing organization?

5. State in what order and in what location supplements are filed in publication binders.

013. Distinguish among publication numbers, titles, and types of indexes.

Basic Numbering Systems. Because of the large number of Air Force publications, a method for identifying them quickly is needed. The Air Force has, therefore, developed a subject and numbering systems. Basic subjects and basic numbers are assigned to publications from the list in AFR 5–4, *Numbering Publications*. Regulations, manuals, and pamphlets have a double number system to simplify reference and control. For example, consider AFR 35–3. The first two digits, 35, make up the basic number. It shows the basic subject of the directive to be Military Personnel. The second number, preceded by a dash (–3), indicates exactly what area of military personnel is covered. In this case, the specific title corresponding to the second number, –3 is Service Dates and Dates of Ranks. The numbers are assigned by the Director of Administrative Services, Headquarters USAF. They identify the publication and, with the title, help you locate the exact information required. It is more fully understood when you refer to a publication by its specific title than by its subject matter. The basic number is the same for related subjects throughout the different types of publications. The second number of the AFR, AFM, or AFP tells what part each area covers. The pamphlet has an additional or third number. The first number is the basic number, the second number provides for grouping under secondary subjects, and the third number is for a more detailed breakdown. This permits closely related subjects to be issued in separate pamphlets with the same basic and secondary numbers. Remember that specific identification is given by the third number.

Supplements. Supplements are identified with the basic publications that they supplement and are numbered in sequence. As an example, if the basic regulation in AFR 4–1, dated 1 October 1982, were to be supplemented by information developed 2 months later, it would be published as ATC Supplement 1 to AFR 4–1, dated 1 December 1982. If this were to be followed with another supplement 2 more months later, it would be identified as ATC Supplement 2 to AFR 4–1, dated 1 February 1983. Remember that every Air Force publication is given a number and title, making it possible to index and file all publications in an orderly fashion. This makes it simple for you to locate any publication quickly and easily for reference purposes.

Indexes for Standard Publications. Suppose you wanted to read about the Battle of Gettysburg. Probably you would select a book on American history to find the information you need. You wouldn't read through the whole book until you happened to find what you wanted, would you? No, you would probably go to the book's index and then turn directly to the indicated pages. For efficiency and saving time, the answer is obvious.

Air Force standard publications and recurring periodicals are indexed numerically with the subjects listed. All Air Force publication indexes use the basic number zero (0) as the first digit.

AFR 0–2, *Numerical Index of Standard and Recurring Air Force Publications,* lists Air Force regulations, manuals, pamphlets, visual aids, recurring periodicals, and obsolete publications; all are listed in numerical order. This is the primary index for standard publications. The index contains five divisions: Recurring Periodicals (such as *TIG Briefs, Airman,* etc.); Visual Aids; Regulations, Manuals, and Pamphlets; Obsolete Publications (rescinded or superseded recently); and Alphabetical List of Subjects and Series Assigned to Air Force Publications. For most publications listed, the following information is given: type, number, date, title, office of primary responsibility (OPR) symbol, and distribution symbol. The latter two, OPR and distribution, are primarily of interest to those who maintain the file. A typical entry looks like this:

No.	*Date*	*Title*	*OPR*	*Distr.*
P 11–6	31 Mar 82	*Nicknames and Exercise Terms* (Microfiche)	DASAS	F

One-letter abbreviations are used in the Number column in AFR 0–2 as follows: regulation, R; manual, M; and pamphlet, P.

AFR 0–2 is revised and reprinted periodically in order to keep the index current. As you are no doubt aware, Air Force publications change frequently.

AFR 0–2 is completely adequate when you know the type and number of a publication. In this case, you merely check the index to see whether your organization has a copy. Then, make sure that yours is the current copy with all changes. AFR –1, *Guide to Indexes, Catalogs, and Lists of Departmental Publications,* may be helpful when you want to determine the applicable directive or directives but know only the subject, or when you want to know what a symbol in AFR –2 indicates. It is the "index of the indexes" and provides much valuable information.

Your command and your base issue indexes similar to the Air Force indexes just discussed. These indexes list directives published at command local level. If you need information about a certain policy, refer to the basic index.

Indexes for Specialized, Miscellaneous, and Other Publications. A number of indexes are standard publications that list publications other than those that are standard or recurring. Some of these indexes are:

- AFR 0–4, *Department of Defense, Joint Chiefs of Staff, and Interservice Publications, and Air Force Acquisition Documents.*
- AFR 0–8, *Numerical Index of Specialty Training Standards.*
- AFR 0–10, Management Control and Authorization Program for Tables of Allowance and Allowance Source Codes for USAF Activities.
- AFR 0–16, Miscellaneous Federal Government and Commercial Publications.

A brief explanation of the types of publications covered by these and other indexes follows.

Specialized Publications. Specialized publications are prepared and issued by Air Force commands concerning some specialized function. They are made available to all organizations involved with the function. Examples of this type of publication are Armed Service Procurement Regulations, Communications Security, Joint Army-Navy-Air Force Publications, OJT Packages, Organization Tables, Tables of Allowance, and Specialty Training Standards. AFR 0–4, AFR 0–8, AFR 0–10, and other indexes (such as AFR 0–5, *Specialized COMSEC Publications)* list various specialized publications.

Miscellaneous (Unnumbered) and Other Publications. Examples of these types of publications are Armed Force Hymnal, US Manual for Courts Martial, Congressional Directory, Flying Arsenal of the Air Force, and other Government agency publications applicable to the Air Force. AFR 0–4 and AFR 0–16 are the main indexes that cover publications from such departments as the Department o f Defense; Joint Chiefs of Staff; Defense Supply Agency; Departments of the Army and of the Navy; American Public Health Association; Department of Labor, State, and Treasury, and other Federal bureaus.

Exercises (013):

1. Air Force Regulation 5–4 contains a list of basic subjects that is important to us. What is the title of this list?

2. Air Force regulations, manuals, and pamphlets normally begin with a two-digit number (34, 35, etc.). What do these numbers indicate, and how are they used?

3. Which of the three groups of numbers below indicates an Air Force pamphlet?
   a. 34–3.
   b. 3–43
   c. 34–3–3

4. What is the primary index for Air Force standard publications?

5. Your supervisor informs you that the AFM that you are reading has been rescinded by a more current index. In which index and in what section was this formation found?

6. Who prepares and issues specialized publications?

014. State how you should determine currency of publications, interpret symbols used in the indexes, and borrow publications.

Using Publications. As a publication user, you are not charged with maintaining files. However, you are responsible for checking the currency of the publications you use. The procedure is similar for both standard or other-than-standard publications. For a standard publication, first go to the official file and check the publication date in the current AFR 0–2. There are several other things you should know about using AFR 0–2. As we indicated earlier, this index lists regulations, manuals, and pamphlets mixed together in one section. Since all three publications may have the same number, a letter symbol shows which it is. The letter R, M, or P precedes the publication number to tell the type of publication. The file clerk writes a status symbol in the left margin in front of each publication ordered for the file. A plus (+) is written for each publication ordered and on hand (a current copy). A dash (–) indicates that a publication is needed and ordered, but a current copy is not on hand. No marks are used for publications not required. If a change to a publication should arrive and the new date is not printed in the index, the clerk indicates the change in red.

Sign-Out Procedures. You may sign-out to borrow a publication from official files. The maximum loan period is 3 days. Don't be too eager to get a copy for your own personal use. There may be a temporary advantage to getting a personal copy, but before long the publication may be obsolete.

Publication Files. To insure that up-to-date information is available, the Air Force prescribes establishment of publications libraries or files. An individual is assigned to each library or file to keep it current. There are two major types of files (libraries).

Master publication library. Such a library is authorized for organization down to wing or base level—usually no lower.

Functional publication library. These libraries are authorized for lower level activities that need them; however, such files are limited to publications that pertain specifically to the mission of the activity.

Exercises (014):

1. To determine that the AFM you are using is current, you check AFR 0–2 and find the the date listed as 13 Sep 72. Your manual has a date of 3 May 73 on the cover sheet. To correct the index error, what action should you take?

2. Looking in the index for AFM 39–62, you notice that someone has placed a dash (–) in front of the number. What does this indicate?

3. If you were to check an AFR out of the official file on 3 May, by what date should you return it?

015. List the basic types of technical orders.

Technical Orders. The aircraft electrical systems specialist maintains Air Force equipment. You, therefore, must know how to use Air Force technical orders because they contain maintenance and operating instructions, identification of parts, and other important information on Air Force equipment.

Technical publications are published and distributed by the Air Force Logistics Command (AFLC). Publications printed by other Department of Defense agencies for equipment are incorporated into the Air Force TO system. These may be printed and bound according to the specifications of the procuring agency. A number is assigned to each of them before it is listed in the pertinent technical order index. The incorporation of these "other" publications into the Air Force system provides maximum coverage of the equipment it possesses.

The Air Force technical order system is authorized by and explained in AFR 8–2, *Air Force Technical Order (TO) System*. However, a detailed explanation of the system is covered in the 00–5 series of technical orders.

There are five basic types of publications in the technical order system which an aircraft electrician uses. They are (1) indexes, (2) technical manuals, (3) time compliance technical orders, (4) methods and procedures technical orders, and (5) abbreviated technical orders.

Technical Order Indexes. These TOs provide personnel with a means of selecting needed TOs. In certain instances, they group the TOs pertinent to specific items of equipment. Also, you can tell the status of a TO in the file. Now, let's look at the various types of TO indexes:

Numerical Index and Requirement Tables. Numerical Index and Requirement Tables (NI&RTs) are listings of TOs within categories (groups) of equipment. These indexes include the necessary information for ordering the TOs. This index group begins with the index of indexes (TO 0–1–01) in which all of the indexes are listed numerically. Actually, the NI&RTs are composed of a series of separate publications. Each NI&RT contains a listing of publications which applies to a specific category of equipment. For example: category 1 designates aircraft TOs, such as TO 1F–15A–2–6; category 33 is concerned with test equipment, such as TO 33D2–4–4–31. Along with the numerical listing, you can find the TO issue date, change date (if any), and security classification (if any); you can also check for the availability of the TO. Standard symbols are used in all NI&RTs to indicate which publications are in the particular file. For example, a plus (+) sign placed next to a TO listing in the NI&RT indicates that the publication is in the file and complete. The minus (–) sign is used to indicate that the publication is required but is either missing or incomplete and on order.

Alphabetical Index. TO0–2–1, *The Alphabetical Index*, provides an easy method for locating the correct TO number group when the type of equipment is known. This TO does not give you the status but refers you to the proper category NI&RT. The list of applicable publications (LOAPs) provides listing of all TOs that apply to a specific weapon or system. The LOAPs enables one to select and become familiar with publications pertinent to a specific weapon or system. The LOAPs also one to select and become familiar with publications pertinent to a specific aircraft. It also helps determine the contents of limited TO files which may need to be established. For a typical example, let's take an F–111A aircraft. To locate all of the TOs relating to the F–111A, we would have to change the aircraft designator to a TO number. To do this, place a 1 in front of the designator and add a –01 on the end. The final designator of the LOAPs TO number is –01; therefore the complete number is 1F–11A–01.

Should we need a TO giving the description and principles of operation for a skid control generator, we could go to the LOAP, open it to the Landing Gear Components and Associated Equipment, and at this point we find TO 1F–111A–2–9–1, *Landing Gear Systems*. Proper use of these indexes will enable you to locate other technical orders needed to perform your duty.

Exercises (015):

1. What type of information is contained in technical orders?

2. What command publishes technical publications?

3. State the function of AFR 8–2 which plays an important function in the technical order system.

4. List the five basic types of technical orders.

5. TO-0-1-01, is often called an index and also by what other name?

016. Identify the technical orders by their parts in the number system.

Technical Order Number System. Technical orders cover a large number of subjects; therefore, a good numbering and filing system is needed so that mechanics can quickly locate information they need.

In our present numbering system, each TO number is divided into three or more parts. Each two adjacent parts are separated by a dash. The first part is a number designator to identify the TO category. The categories are:

Category 0—Indexes.
Category 00—General Technical Orders.
Category 1—Aircraft General.
Category 2 through 16—Aircraft and Missile Equipment.
Category 21—Guided Missiles.
Category 22-Aerospace TOs.
Categories 31 through 50—Ground Equipment.

Now, we add a letter to the category number to indicate the type of equipment. Examples of such combinations follow.

Category 1 identifies general aircraft; by adding a "B" after the "1," it becomes 1B—Bomber Aircraft, or by adding a "C" after the "1," it becomes 1C—Cargo Aircraft. An "F" would make it a 1F—Fighter Aircraft. Category 4 is Aircraft Landing Gear Components; e.g., 4—Aircraft Landing Gear Components. By adding a "B" after the "4," it becomes 4B—Aircraft Brakes; or by adding an "S" after the "4," it becomes 4S—Aircraft Struts.

The second part of the TO number gives the model and series; and the third part gives the type of instruction, with a possible fourth number as a further breakdown of the type of instructions. Note this example: 1F-4C-4-1:

Category	1
Type	F
Model	-4
Series of model	C
Type of instruction	-4
First (IPB) section	-1

A -1 as the second part of our number in aircraft and equipment TOs indicates a general TO that applies to two or more aircraft or pieces of equipment within that category.

Selecting Technical Orders. Remember that all technical orders are divided into categories. A glance at the TO number will identify the type of information the TO contains. However, this is not the whole picture. To know how to make effective use of TOs you must follow some orderly procedure. Just as in most jobs, you progress from the known to the unknown. First you must know what you need information on. Is it a piece of equipment, a component part, or a whole system? When you know this, then look for the applicable TO.

Procedures required to locate a specific technical order are given in the following steps:

Step 1. Determine the category which covers the equipment. A listing of the categories is in TO 0-1-01.

Step 2. Sometimes the equipment is of such a nature that it is difficult to determine the category. In this case, use the alphabetical index (TO 0-2-1) to find the category.

Step 3. Go to the numerical index for the category (TO 0-1-1-2, 0-1-4, 0-1-9-2, 0-1-0-3, etc.).

Step 4. Use the table of contents of the category index to locate the section for that equipment; then go into the index to find the exact model and type. Write down the TO number, the date of basic issue, and any changes that are noted.

Step 5. Locate the binder that contains the desired TO.

Step 6. Check the number and dates against the ones you wrote down from the index to insure that you have the latest TO.

Step 7. Use the table of contents to locate the exact section or page rather than thumbing through the TO. Most large TOs have a table of contents in the front, a table of contents for each section, and an alphabetical index in the rear.

Exercises (016):

1. In the list below, indicate only those technical orders that pertain to aircraft and missile equipment by placing a check beside the alphabet.

____ a. 2E7-2-4-1.
____ b. 1F-86D-2.
____ c. 11F3-2-3-4.
____ d. 12R4-ARM21-3-67.
____ e. —5-3.
____ f. 0-2—3.
____ g. 21K3-4-6.
____ h. 33D3-2-269-8.
____ i. 50F5-2852-3-4.
____ j. 13M4-5-3-3.
____ k. 14M2-3-4-3.
____ l. 3M3-3-3-3.
____ m. 34G-3-5-3.
____ n. 12R4-6-34-2.
____ o. 11A3-4-4-501.
____ p. 4B4-3-3-3.
____ q. 31P3-5-3.

2. Using this number as an example, 1F-105-2-6, identify the digit that indicates the type of instruction contained.

017. Differentiate among the methods of updating technical orders and state procedures in updating TOs.

Methods of Updating TOs. Aircraft can be modified by adding systems or changing parts. When this takes place, the information in the TO for that aircraft or part must be changed. This is done through the use of TO revisions, changes, supplements, and rescissions.

Revisions. A revision is a completely new edition of an existing TO. It replaces the original and includes all existing changes. A revision is normally issued when changed pages total 80 percent or more of the basic TO. Revisions are normally made instead of changes when the basic TO consists of eight pages or less. A revision carries a new basic date and is treated as a new TO. When revisions are received, the replacement note on the title page must be checked against the title page of the TO being replaced. If these dates agree, the old TO should be removed and the new replacement TO filed.

Changes. Changes are issued when only part of existing TOs are affected. The changed pages replace the correspondingly numbered pages. All replaced pages must be removed and discarded.

When changes are received, the complete change must be checked against the new listing on the list of effective pages. This list is on the A page (back of the title page). Notice here that it says, "One a changed page, the portion of the text affected by the latest change is indicated by a vertical line, or other change symbol, in the outer margin of the page. Changes to illustrations are indicated by miniature pointing hands. Changes to wiring diagrams are indicated by shaded areas."

TO page supplement (TOPS). Usually, TOPS are printed on green paper and contain additional material that cannot be fully included on a replacement page. They are normally issued if time and circumstances prevent issuing a standard change. Additional pages are issued and inserted so that they face the affected pages. TOPS changes should include a standard title and A page and should be numbered in the same sequential numerical order as the regular changes. The changed pages must include only the changed paragraph or sentence rather than the entire page. Also, the changed data is placed (filed) next to the page containing the outdated instructions. Inserted pages are given the preceding page number plus capital letter suffixes in consecutive order.

Supplements. Supplements are issued as separate TOs to augment or change data in basic TOs. This is done when the added material may not fit into the basic TO very well.

Routine supplements. Routine supplements are identified by the word "supplement" and an alphabetic suffix to the basic publication number. The first supplement normally begins with the suffix letter "C." These are filed to the rear of the basic publication in alphabetical order. The supplement number is then written on the title page of the basic TO. The supplement number can be found on the supplement title page.

Safety and operational supplements. Safety supplements are identified by the first (title) page being printed with a border of red SSs and with other important information in red. The words "Safety Supplement" appear at the top and bottom of the title page. The supplement number contains two Ss.

The same format applies to operational supplements except that the first (title) page is printed with a border of black OSs, and with the words "Operational Supplement" at the top and bottom of this page, and with all other information appearing in black. The supplement number contains a single S.

Safety and operation supplements are filed in numerical sequence, by date, in front of the basic TO. When safety and operational supplements have the same date, the safety supplement is filed in front. All other supplements are filed in numerical or alphabetical sequence, as applicable, behind the basic TO. Don't forget to make reference to both of these types of supplements on title page of the basic TO.

Rescissions. TOs are rescinded when the information they contain is no longer required. The material may have been incorporated in other publications, or it may no longer be needed. A good example is TCTOs which have automatic rescission dates. Publications are not removed from the files until listed as rescinded in the NI&RT.

Exercises (017):

1. List the methods used to keep technical orders current and up to date.

2. When should a revision be issued?

3. How are changes to illustrations indicated?

4. Where would you look to find out if a page in a TO is an original or a change?

5. When must a TO page supplement (TOPS) be issued?

6. How are safety and operational supplements filed?

018. Describe the contents of technical manuals in terms of how an electrician would use them.

Technical Manuals. Technical manuals are TOs. They contain detailed instructions for operation, maintenance, service, overhaul, installation, and inspection of (in our case) Air Force equipment. Technical manuals are grouped into main categories covering aircraft, missiles, special weapons, and other equipment. As an aircraft electrical systems specialist, you will be greatly concerned with aircraft technical manuals. To find the technical manuals for the F–111A aircraft, you would add 1F–111A in front of the following:

–06 through –09, Work Unit Code Manual.

−1, Flight Manual.
−2, Maintenance Instructions.
−4, Illustrated Parts Breakdown (IPB).
−6, Inspection Requirements.

Another group that you will be dealing with identifies component and equipment categories. These are a large number of categories, covering such items as aircraft accessories through ground equipment. Technical manuals may be numbered in increments of 10 to show modifications to the equipment. For example, −3 overhaul instructions could be listed as −13, −23, through −493. The 3 would still signify overhaul instructions, but there has been a change to equipment, such as:

9H–4–127–3 O/H with P/B—Solenoid Valve P/N 6024 "C–130B."
9H8–4–127–13 O/H with P/B —Solenoid Valve P/N 6204–4 "C–130E."

For small pieces of equipment, the different types of maintenance instructions may be combined. The −3 shown in the example above covers overhaul (O/H) and parts breakdown (P/B). A −1 could cover operation, field maintenance, overhaul, and parts breakdown. This type of dash number identifies the first part of the instructions when two or more types are combined.

Time Compliance Technical Orders (TCTOs). This time compliance technical order concerns work that must be done within a certain time limit. TCTOs provide for modifications of Air Force equipment or furnish instructions concerning inspections and operating procedures.

Time compliance technical orders are grouped according to their urgency. Notes preceding the text state the degree of the urgency; for instance, when the work will be done, and by whom it will be performed. The three major types of TCTOs are Immediate Action, Urgent Action,and Routine Action; a fourth type, somewhat different from these, is the Interim TCTO.

Immediate Action. Immediate Action TCTOs are issued to correct existing unsafe conditions that could result in fatal or serious injury to personnel. They are also issued to prevent possible damage to, or destruction of, valuable property. These TCTOs require immediate action. They will ground aircraft, prevent the launch of missiles, and discontinue the use of ground or personal equipment. On the top of the first page, the words IMMEDIATE ACTION are printed in red. Red Xs are printed around the border of the page. The red Xs provide distinctive identification and correspond to the symbol used on maintenance forms. For example, upon receipt of an Immediate Action TCTO, the aircraft is grounded and an exceptional release is not allowed. Immmediate Action TCTOs have an automatic rescission (canceled) date of 6 months after issue date.

Urgent Action. Urgent Action TCTOs take into consideration combat requirements versus potentially hazardous conditions that may exist. These factors might result in injury to people, damage to property, or unacceptable loss of combat efficiency. Such conditions and risk can be tolerated for only a definite time period. On top of the first page, the words URGENT ACTION are printed in red. A series of red diagonals, alternately spaced with circled red Xs are printed around the border of the page. Upon receipt of the Urgent Action TCTO, the aircraft is placed in a red diagonal status during the specified time limit. This period of time could be from 1 to 10 days. After this time expires, maintenance forms must be upgraded to a circled red X until compliance. The automatic rescission date is 12 months after date of issue.

Routine Action. Routine Action TCTOs contain instructions to remedy defects of equipment or faulty procedures. Failure to comply might reduce operational life, affect efficiency, or create a hazard through prolonged usage. These TCTOs are printed on plain white paper without distinguishing red border symbols. These TCTOs are of two types, determined by who must do the work. For Routine Action category 1, the work is done by organizational/intermediate-level maintenance. These TCTOs have a compliance time of 11 to 90 days. After the time limit expires, the aircraft is grounded until compliance is made. Automatic rescission is 12 months after date of issue. For Routine Action Category II TCTOs, the work is done by a depot. Such action is scheduled for the next inspection-and-repair-as-necessary (IRAN) procedure or when the unit is overhauled. Exceptional release is not required. The normal automatic rescission date may not exceed 48 months after date of issue.

Interim. Interim TCTOs are different from others we have discussed. They are issued when the need for instructions can't wait for formal printing. The issuer uses radiograms, telegrams, teletype, or airmail to issue instructions. This method of issue may also be used with Immediate Action or Urgent Action TCTOs. Interim TCTOs constitute a temporary TO and are replaced by a formal printed copy within 10 workdays. When an Interim TCTO is issued, it is identified thus: "This is Interim Urgent Action TCTO 1F–1–11A–501." TCTOs are always numbered −501 and higher for the final designator.

Job Guide Manuals (JGs). Job guide manuals provide complete detailed instructions for on-aircraft maintenance such as operational checks, adjustments, removal, and installation. Each job guide contains complete start-to-finish maintenance instructions for each task in logical step-by-step sequence. Instructions are fully supplemented by detailed illustrations which show what each component looks like and where it is located. Theory of operation and general maintenance information is contained in complementary, standard size technical orders which are not normally required at the job site. These additional technical orders, besides the job guides, are general aircraft manuals, maintenance support manuals, troubleshooting manuals, and maintenance index manuals.

Organization. The JGs are organized by aircraft subsystems. Wherever possible, instructions for all maintenance tasks for a subsystem are combined in one JG. Where this would result in a manual exceeding approximately 200 pages, normally information for a subsystem is split into two manuals.

Table of contents. A table of contents in the front of each JG lists the tasks in that manual and indicates applicable page numbers.

Input conditions. Each task (section) is complete within itself and provides, or refers to, all information needed for

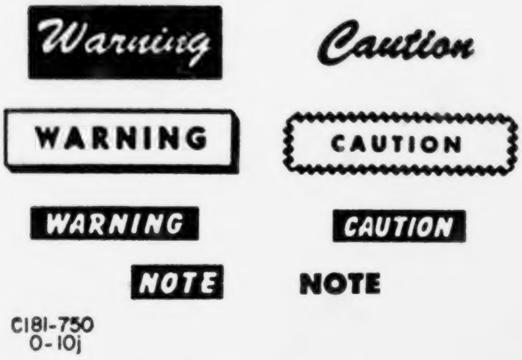


Figure 2-1. Maintenance reminders.

the job. The first page (or pages) defines the "input conditions" for the task. The input conditions page(s) define(s) the following items.

Applicable serial numbers. These numbers indicate aircraft on which the task is applicable. When the word ALL is used, the task applies to all aircraft within that series. When the task is not applicable to all aircraft due to configuration differences resulting from TCTOs, only aircraft serial numbers to which the task applies are listed.

Supplies. All expendable supplies needed to accomplish the activity are listed.

Personnel required. This input condition defines the minimum number of personnel required to accomplish the task safely and efficiently. When more than one person is needed, specific assignments are indicated. If an assistant is required for part of the task, or a specialist for a specific function, the need is noted. Their services, however, are not actually required until called for in the step-by-step instructions. An assistant may be of any skill level and may perform tasks only as directed by the primary technician. A specialist is a person qualified and competent in a specific area, such as environmental or electrical, etc.

Equipment condition. This specifies any special aircraft conditions which must be met before the task can be accomplished. For example, does the aircraft need to be chocked, jacked, or defueled? Any necessary WARNINGS or CAUTIONS are also included under this heading.

Special tools and test equipment. This lists any special tools, test equipment, or ground-handling equipment required. Acceptable alternate equipment is also listed, when available. Common tools are not listed.

Task index. In activities which include more than one task, a task index follows the input condition page(s). This task index lists all tasks in the activity (major task) and the page on which each starts. After the necessary input conditions are met, any task may be accomplished separately, if desired.

Instructions. Detailed, step-by-step instructions follow the input conditions (or task index, if required). Instructions are fully supported by illustrations (on the facings or on foldout pages at the end of each task). If text and illustrations are on facing pages, each illustration pertains only to instructions on the facing page. When foldout illustrations are used, the illustration page is referenced immediately after the task title. An identifying number appears in parentheses after each component in the instructions. This number corresponds to component identification numbers on the applicable illustration.

Precautions. Warnings, cautions, and notes appear wherever necessary in the instructions. They always precede the step to which they apply, alerting the technician to conditions which should be established before the step is performed. They also let the person know what to expect when performing the step. Pay particular attention to such precautionary words as "Warning," "Caution," and "Note." Not only will these give you valuable information, but also you should know their meaning. Thus, a prefatory "Warning" means that a violation of the procedures that follow could result in injury or death. The word "Caution" entered before procedures means that the equipment involved may be damaged if those procedures are not observed. For all of this, see figure 2-1 which is an excerpt from a section of a TO. Notice that the word "Caution" is set in boldface type, with a border of waving lines. Remember that the word "Note" is used to add emphasis to essential material which follows it.

Exercises (018):

1. Among a stack of paper that just arrived in the shop, you notice a corner of one sticking out and it is bordered with many red Xs. You should be able to identify this form without removing it from the stack. State what type TCTO it is, and what the automatic rescission date is.

2. The aircraft electrical systems specialist shop received an immediate action TCTO with an issue date of 13 June 1977. State the date that should appear as the rescission date if indicated.

3. Which type of TCTO must be accomplished by depot?

4. What type of technical manual is a 1B-52D-6?

5. How are job guides organized?

6. Where will you find the "personnel required" in a job guide?

7. What does the word "Warning" mean in a maintenance manual?

019. State when abbreviated TOs are used and state the type of information you use in methods and procedures TOs.

Abbreviated Technical Orders. TOs of this type are primarily work simplification devices. They are condensed versions of TOs and include inspection workcards, sequence charts, and checklists as described below:

Inspection workcards. Inspection workcards prescribe minimum inspection requirements and are to be used while performing inspections. To identify these TOs by number, the "WC" in TO 1F-111D-6WC-3 identifies this as a workcard. The information is taken from the -6 inspection requirements TO. During an inspection, maintenance personnel should observe both the equipment named in the cards and other components in the surrounding area for obvious defects. The requirements listed in the body of the card are arranged by work areas. They are sequenced in the most logical and practical order of accomplishment. Cards are also grouped by the type of specialist required and by work area. This arrangement allows the inspections listed on any particular card to be performed by one individual and permits the assignment of the specialist to a certain work area to do a specific job or a series of jobs. To further aid in making work assignments, the inspection workcard numbers may be plotted on a sequence chart to provide the desired work schedule or sequence in which all predictable or routine maintenance can best be done.

Sequence charts. Sequence charts depict a basic planned work schedule. They also serve as a guide in preparing the actual work schedules. These charts provide a visual means of controlling the assignment of work during an inspection and constitute a ready reference for determining the progress of the inspection.

Checklists. Although not used for inspection or scheduling, checklists are employed to perform various maintenance tasks or operations in the most practical sequence. These abbreviated TOs list TO procedures in a condensed form. For example, if an aircraft has to be taken into the hangar in order to perform an inspection, checklists would be used to defuel, tow the aircraft, and even jack the aircraft, as necessary.

Methods and Procedures Technical Orders (MPTOs). These technical orders establish policies, methods, and procedures of a general nature and do not relate to specific equipment. Thus, the MPTO differs from a technical manual, which deals with specific aircraft, missiles, or other items of equipment. In other words, if the information does not fall into the category of aircraft, missiles, or other pieces of equipment, then more than likely it will be categorized as a methods and procedures TO. Two examples are the TO 00-20-2, *Maintenance Data Collection System* and the TO 00-5-2, *Technical Order Distribution System*. Another easy way of determining whether or not a TO is a methods and procedure TO is by consulting the first digits of the technical order number. All methods and procedures TOs start with 00 as the category number. MPTOs are also divided into two classes. One class involves policies, methods, and procedure relating to maintenance management or administration, such as 00-35D-54, *USAF Material Deficiency Reporting and Investigating System*. The other class involves policies, methods, and procedures relating to equipment in general, such as 00-25-234. (General Shop Practice Requirements for the Repair, Maintenance and Test of Electronic Equipment. You will probably use 00-25-234 quite often in your career. You will also use 00-20-2, *Maintenance Data Collection System*, for doing the paperwork part of jobs.

Exercises (019):

1. Which abbreviated TO is used to prepare work schedules?

2. Which abbreviated TO would you use to tow an aircraft?

3. What type of information would you find in an MPTO?

020. Cite proper use of the technical order improvement report in a given instance, and cite responsbility for deficiency reports.

Technical Order Deficiency Reporting. The term "deficiency" denotes an error or defect which changes the meaning of instructions. It could also denote insufficient information to adequately perform a task or function. "Deficiency" does not include minor errors of a nontechnical nature. Example: misspelled words, typographical errors, and improper sequencing of pages. An AFTO Form 22, Technical Order System Publication Improvement Report and Reply, is initiated by the person who discovers the deficiency. This person's supervisor checks to see that the deficiency is valid and important enough for submission. The deficiency report then goes to Quality Control for approval. From there it is sent to the Air Force Logistics Command (AFLC) depot indicated in the Storage and Issue column of NI&RTs. AFTO Forms 22 are submitted in one of the three priorities—emergency, urgent, or routine. Before you submit the report, consult with Quality Control. They will advise and assist you.

AFLC takes action on Emergency reports within 48 hours after receipt. On urgent reports, action is taken within 30 days. Unless routine reports are disapproved, AFLC makes no reply to them. Changes to TOs are published within 90 to 180 days.

Each of us has the responsibility for reporting any TO deficiency to insure that we have the best, up-to-date TOs possible.

Exercises (020):

1. While using a technical order you find what you believe is an error because step 13 required external

power to be disconnected. Step 14 requires a test set to be connected, step 15 directs application of external power, and step 16 directs pulling circuit brakers A7, A9, and A11. Equipment damage will result if power is applied because the circuit breakers are pulled. Therefore, steps 17 through 19 could not be completed satisfactorily. Should you submit a deficiency report on this type of error? Explain.

2. Name the major command that processes submitted deficiency reports.

3. Name the maintenance branch responsible for assisting you in submitting deficiency reports.

2-2. Supply Discipline

Money is something which concerns us all. We are concerned with stretching it out and making ends meet. In this section, we discuss methods of saving money for ourselves and the Air Force.

To accomplish the mission of the Air Force, we buy many thousands of items. Among these are spare parts, special tools, maintenance equipment, pencils, paper clips, and other items. The cost runs into billions of dollars. This property is stored, issued, and reissued or shipped. This cycle may be repeated several times before an item is no longer usable and is sold for scrap. At this very moment there are most likely reparable items in your shop that need to get back into the supply pipeline. It is your responsibility to help get this done.

021. State the basic principles of supply discipline.

Principles of Supply Discipline. All personnel working for the Air Force must treat Government property as if it were their own. This applies to officers, airmen, and civilians alike. When you use a piece of Government property it is like borrowing a book from the library. Sooner or later you must return it, and you are the one responsible for it.

You should clearly understand your responsibility for Government property; otherwise, there may come a time when the Air Force will ask you to pay for a piece of equipment. Your tax money has already helped purchase this equipment. However, you may have to pay for it again, and you won't even get to keep the item if it is found later. Your applied knowledge of custodian rules and procedures keeps you free from monetary responsibilities for damage or loss of Government property.

Good business practices are important. Obtaining more supplies than needed to accomplish the mission of your organization is not a good business practice. You normally do not purchase four additional tires as spares for your automobile merely because it has four wheels. Neither is it necessary to buy a spare engine, because the original engine should operate for more than 50,000 miles. These same ideas are followed when you obtain supplies for the Air Force. We call these business practices the *principles of supply discipline*. We want you to know and practice these principles.

Exercises (021):

1. List those persons who can be held responsible for equipment they use in their jobs.

2. After paying for lost equipment, do you own the equipment if it is ever found?

3. Having 23 people assigned to night shift and 12 assigned to day shift, the supervisor tells you to order 288 flashlight batteries from supply. Indicate how the supervisor might have erred.

022. Cite responsibility for Air Force public property in specified cases.

Responsibility for Public Property. The property you use in your duties (whether it is a desk, a toolbox, a truck, or an electronic test stand) is your responsibility. Good management dictates that the person who is using the property be responsible for its care. Everyone in the Air Force is responsible for some type of property. For one person, it may be a shop full of equipment; for another, a bed blanket. In any case, property responsibility is a part of any position in the Air Force.

Because the Air Force is large and complex, it is necessary to assign responsibility for property; otherwise, the Air Force can never be sure that its property is adequately safeguarded. A lack of responsibility would cause the whole system to fall into wastefulness and carelessness. Let's first determine where responsibility originates.

The money used to buy property comes from all of us in the form of taxes. Therefore, the title to this property is not held by any one individual, it is jointly owned by all of us. There is no problem finding who is responsible for a personal item. We know that if our personal property is abused, we must pay for its repair or replacement. Now then, who is to be responsible for the millions of Air Force items costing billions of dollars? Congress has the responsibility of appropriating the money to buy this property; Congress also passed the law to hold certain individuals responsible for public property.

Congress passed such a Federal law in March 1894. This law is the authority for regulations concerning responsibility for public property. The Air Force explains the application of this law in AFR 67-10, Responsibility for Management of Public Property in Possession of the Air

Force. Certain officers, airmen, and civilian employees are designated as supervisors. Possibly you are one of them or will be in the near future. As a supervisor, you are responsible for carrying out the orders and directives of the commander. As a representative of the commander, you have certain responsibilities for subordinates and property. However, if you are supervising several workers, you cannot be looking over the shoulder of each worker at all times. Therefore, like the commander, you as the supervisor cannot be solely responsible for the property in your activity.

In your duty section, you, your supervisor, and your commander have the responsibility for property you are using. If this property should be damaged, the circumstances determine who is responsible for the damages.

Property responsibility is imposed by law on all officers, airmen, and civilian employees and cannot be delegated—only shared. This obligation includes pecuniary liability. This means that we must make good the loss, destruction, or damage of property caused by our maladministration or negligence. This responsibility is the obligation of an individual. This is so regardless of duty assignment, level of command, or supervision. Depending upon the circumstances, any person, military or civilian, may be charged with one or more of three types of responsibility: command, supervisory, and custodial. When you buy an article from a store, the moment the sales clerk completes the transaction, the store drops its accountability. You then become responsible for its proper use, care, maintenance, and custody.

Similarly, when a stock clerk issues you an Air Force item, the clerk's accountability is dropped. However, you do not become the owner of the item; instead, the Air Force retains ownership and you assume responsibility for the care and protection of the item as provided by applicable regulations. Stated in other words, the property you use in your duties, whether it is a desk, a typewriter, a truck, or a grinding machine, is your responsibility. It is important to note that property responsibility is in no way lessened by the fact that the issuing authority has terminated accountability.

Exercises (022):

1. State why responsibility for Air Force equipment is assigned to an individual.

2. Cite the authority and application of the law that deals with responsibility for public property in possession of the Air Force.

3. Cite who has the responsibility, accountability, and ownership of the toolbox and its contents which you use on the job.

023. State the commander's responsibilities for equipment and property.

Command Responsibility. Commanders at any level have command responsibility for all property under their jurisdiction. Commanders are not exempt from pecuniary liability for loss, damage, or destruction of Government property within their command.

A commander must insure that records of supply transactions are accurately kept. To fulfill this duty, a commander must rely upon the capabilities of the people in the command. They must know the records to be maintained and the procedures for air maintenance. It would be almost impossible for the commander to know all the minute details required for recordkeeping. Commanders must see that the people filling these positions trained and are trustworthy. To insure the economical use of Air Force equipment and supplies, the commander must set an example such as seeing that supplies are used for their intended purposes and not wasted. Numerous items may be used for purposes for which they were not intended; and if these items are more costly than the item they replace, a real loss of purchase monies results.

The commander or a representative must make frequent visits to base activities to insure that Air Force property is being properly cared for and safeguarded. Although AFR 67–10 states that those visits be made often, the time intervals are not stated. The needs of the operation determine the intervals of the visits. When the activity is operating smoothly, the visits need not to be as frequent.

To discharge property responsibilities, the commander must issue instructions and directives. These should be timely enough to take care of any changes in the mission. They should be issued as required to insure that Air Force property is used for its intended purpose, properly maintained, and properly secured.

Exercises (023):

1. The wing commander has just informed the squadron commander that a squadron maintenance truck full of people is sitting in front of the base exchange. The squadron commander is also informed that a similar occurrence will result in all trucks being assigned to the regular motor pool. State why the wing commander would be so concerned with the maintenance truck.

2. State what determines how often a commander visits command sections.

3. State ways the commander may discharge responsibilities to subordinates.

024. Cite the supervisor's responsibility for equipment and property.

Supervisory Responsibility. Supervisors normally are located near the property for which they are responsible. Although not having as many responsibilities as commanders, supervisors have more direct control over the property. Supervisory responsibility applies to any person who exercises supervision over the property. Supervisory responsibility of property applies when it is received, in use, in transit, in storage, or undergoing modification or repair. It covers the property from the time the Air Force buys it until it is consumed or sold. AFR 67-10 tells about responsibility for management of public property, and also tells about supervisory responsibilities.

In situations where commanders have personnel working directly under their supervision, they have supervisory as well as command responsibilities.

The supervisor must insure that subordinates know the appropriate local directives as well as higher publications. Subordinates must also be trained in supply discipline.

Custodial Responsibility. Custodial responsibility is that responsibility which must be assumed by an individual who has acquired physical possession of Government property. The word "custodian" means caretaker. A person has custodial responsibility if the property (1) is issued for official or personal use whether or not the person has signed a receipt for it; (2) is under direct control for storage, use, custody, or safeguarding; or (3) is found (indicating possible loss, theft, or abandonment) under circumstances requiring personal care, custody, or protection.

Property issued to an individual does not become private property by the act of issue (whether the issue was for official or personal use). It remains at all times public property and, as such, must be adequately safeguarded against misuse or theft.

A person may, and often does, have more than one type of responsibility. An example would be the desk and chair used by the commander. The commander has both command and custodial responsibility. A supervisor of a secretary has supervisory responsibilities for the desk and other office equipment used by the secretary. Supervisors also have custodial responsibility for their desks and office equipment. From these examples, we can think of many conditions which could place more than one type of responsibility with an individual. The person finding public property is responsible for its care and protection until it can be returned to the responsible person. The person finding the property is required by AFR 67-10 to place it back into the supply channels.

Exercises (024):

1. Cite the reason the supervisor is often given the responsibility of control over equipment and supplies.

2. Cite the conditions under which the commander may also be assigned supervisory responsibility.

3. The supervisor may require personnel to read AFR 67-10. What is the subject of this AFR?

4. Under what conditions should you assume custodial responsibility for Air Force equipment?

5. While following a supply truck loaded with small boxes, you notice two boxes fall from it. Describe what actions are required of you according to AFR 67-10.

6. What is custodial responsibility?

025. Cite procedures used to be relieved from property responsibility and define pecuniary liability.

Relief from Property Responsibility and Pecuniary Liability. We have mentioned the circumstances under which property responsibility is assumed. How can we be relieved of property responsibility? The condition of the property is an important factor when we are being relieved of property responsibility. The property for which we seek relief of responsibility may be serviceable, unserviceable through fair wear and tear, lost, damaged, or destroyed. Pecuniary liability may be involved when you are being relieved from property responsibility. This applies to property that was lost, damaged, or destroyed as a result of causes other than fair wear and tear. (Pecuniary liability means the responsible person must pay for the loss.) The methods of relief from property responsibility depend upon whether or not the individual admits pecuniary liability. For the time being, we end our discussion of relief from property responsibility under these conditions. Instead, we explain how to be relieved where pecuniary liability is not involved. There are two ways by which this can be done—by turn-in or by transfer. These apply to property that is serviceable or unserviceable. However, items that are not serviceable must be damaged by fair wear and tear, and not by neglect or unauthorized cannibalization.

Turn-in. The turn-in of property means putting it back into the supply channels. If the property is not serviceable, it is transferred to a repair activity. If it is beyond repair, it is transferred to the disposal unit. Procedure for disposal depends on the property involved. Serviceable items are turned in for reissue. When you have an item signed out from EMO (equipment management office) and you don't need it, turn it in. For instance, suppose you have an adding machine signed out and it is no longer needed. Return it to EMO and pick up your receipt. If no one else in the organization has a requirement for the machine, EMO returns it to supply. Supply will then look inquire if another organization has a need for the machine. If no requirement for the machine exists, it may be disposed of. This can be done by shipping it to another base, to depot, or to the local defense property disposal activity. Each of these transactions must be documented to relieve each individual or activity of responsibility for the machine. Such transactions occur frequently. When the turn-in is properly documented, relief of responsibility and accountability for the property is obtained. Now we discuss the methods that are used to obtain relief from property responsibility when property or people are transferred.

Property transfer. The transfer of property, as used here, means changing its physcial location or user. If the user of the property changes, custodial responsibility moves to the new user. For example, a commander desiring a new desk, may send the old one to a section that needs it. Custodial responsibility for the old desk then moves to the user in the other section. Another example is provided by an item that has a serial number. The physical location of such items is entered on property records. An example would be transferring a typewriter from the orderly room to Quality Control. This type of transfer relives the people in the orderly room of supervisory and custodial responsibilities; however, supervisory and custodial responsibilities are then assumed by Quality Control. The command responsibility for the typewriter remains with the squadron commander. Had the typewriter been transferred to another squadron, the commander would be relieved. These examples show that property responsibility goes with custody or jurisdiction.

Transfer of personnel. When a person who is responsible for property is transferred and the property remains with the organization, property responsibility stays in the organization. Some of the items of property for which an individual has custodial responsibility may be returned to supply. Your records and hand receipt then are cleared and you are free to depart from the base. Let's say the individual is a supervisor and his replacement is not on base. Let's say you are a supervisor and your replacement is not on supervisor is normally held responsible for the property until the replacement arrives.

Exercises (025):

1. Define pecuniary liability.

2. The shop supervisor wants personnel to turn in unserviceable parts as soon as possible. Cite the reasons for this action.

3. Your shop has 12 extra straight back chairs due to personnel losses. The supervisor wants to turn them in to EMO so they can be issued to Sergeant Beck, the shop chief in the next room, who has a need for them. Why would she choose to turn them in rather than transfer the property?

026. State factors used in determining supply authorization quantities.

Supply Authorization. The equipment authorized for your unit is based on two general factors, the unit mission and the number of people. These factors are interrelated. For example, if performance of the mission requires certain vehicles, then operator personnel must be authorized. As people are authorized, quantities of other types of equipment are based on the number of people.

The equipment authorized your unit is based on USAF allowance documents. These documents reflect the average minimum quantities of equipment items needed to accomplish the mission. However, the allowance documents do not necessarily reflect the exact quantities your unit will be authorized. Exact quantities are determined by major commands and base EMOs. They're influenced by such factors as the number of aircraft to be maintained, the size of the workload, the type of maintenance performed, the number of personnel, and the climatic conditions.

Table of Allowances (TAs). The USAF Tables of Allowance are authorization sources which are quoted when we submit requests for issue. AFR 0-10, *Management Control and Authorization Program for Tables of Allowance and Allowance Source Codes for USAF Activities,* is the index of TAs. TAs provide a list of items of equipment in the quantity normally required by the mission of an Air Force activity. Repair parts are not listed. Some examples of TAs are:

a. TA 737, *Aircraft Electrical Systems Maintenance.* (For an electric shop.)

b. TA 333, F/RF-4 *Aircraft Organizational/Intermediate Maintenance.* (For an organization performing aircraft maintenance.)

c. TA 757, *Aircraft Maintenance.* (F-100, F-104, F-105, F/B-111, T-28, T-33, T-39 and A-7 aircraft). (For an organization performing aircraft maintenance.)

d. TA 016, *Special Electrical Systems Maintenance.* (For an electric shop.)

Expendable Supplies. These are items which are either consumed or lose their original identity when incorporated into another assembly. Office supplies such as paper and pencils are examples of items consumed in use. Bench stock items, such as nuts, bulk hose, seals, and repair kits are items that are incorporated into another assembly.

Bench stock is a working stock of nonrecoverable items. It is required to provide uninterrupted operation and expedite maintenance. Bench stock for one shop may be authorized for each maintenance shop area, or the bench stock may be combined when two or more shops occupy the same area.

Transactions with Equipment Management Office (EMO) and Base Supply Office (BASO). EMO is responsible for control of the base equipment management system. So far as your unit is concerned, EMO is the source of supply. Also, it receives all equipment requests for nonexpendable items listed on the TA for your organization. Examples of these items are tools, machines, and clothing.

BASO controls and issues repair parts and maintenance items. These items fall into two categories: (1) bench stock, which consists of miscellaneous items of expendable hardware and (2) repair cycle items. BASO also issues local purchase items such as pencils and paper clips.

For requesting supplies, you will most likely find both local forms and Air Force forms used; therefore, we will not discuss the form numbers. We will list some of the information that is required by them. Keep in mind that these forms have a dual purpose; they are used for either issue or turn-in of equipment or supplies. Turn-in is appropriate for excess of unserviceable property. Your unit supply custodian will indicate which action is requested. The following information goes on the form:

a. Date of request and unit designation.

b. A unit supply request number (for identification or followup action).

c. The name and telephone number of the unit supply custodian.

d. Equipment stock number or part number and name or description of the item.

e. Justification of request which must include citing the allowance documents applicable and a brief statement of circumstances.

f. The quantity required.

g. A certification by the commander or a representative that the requirement is valid.

Exercises (026):

1. What factor determines the equipment authorized by a TA.

2. USAF allowance documents reflect the average minimum equipment needed to accomplish the mission. Who determines what quantities are issued?

3. State factors that may be used to arrive at a specific number of authorized pieces of equipment.

4. Why are bench stock items stocked?

5. Which supply branch normally resupplies the bench stock items?

2-3. Maintenance Data Collection (MDC) System

The maintenance data collection system provides for the recording of maintenance actions as they are completed. The recorded information is then keypunched and processed in report form for management information requirements. This section of your CDC is designed to give you a comprehensive view of the importance of the MDC system and how the data is documented and reproduced in report forms.

027. List the benefits that a maintenance activity can derive from the MDC systems.

Use of MDC Information. There are many and varied uses made of MDC information, starting with workcenters and running through the complete spectrum of maintenance and material management. This information is also provided to industry for consideration in new equipment design. Specific uses of the output products from computer programs are included in USAF directives. These uses are also included in command regulations and manuals that prescribe management requirements.

Base-level use of maintenance data is prescribed in AFM 66-267, *Maintenance Data Collection System*. At base level, the MDC system provides the means for managing assigned equipment resources, and planning and scheduling maintenance. It also provides the means for validating and initiating corrective action on maintenance problems. The MDC system is a key source of information for assessing maintenance requirements. More specifically, at base level the MDC system provides:

a. Production credit information regarding the type of work accomplished, the workcenter that did the work, and the equipment on which the work was completed.

b. Equipment maintenance schedules and inventory information for maintenance requirements established on a calendar basis.

c. Direct labor hour expenditures by workcenter and by type of equipment, in either detailed or summary form. This includes labor expended for tenant activities or special projects.

d. Material failures and equipment discrepancies in composite form by type and model of equipment.

e. Configuration status accounting for both outstanding and accomplished modifications.

Date in the MDC system is made available to base-level maintenance activities through daily or monthly reports. Daily error listings are also produced at base level to aid in maintaining accurate information.

The primary use of data provided to AFLC through the MDC system is to satisfy the maintenance engineering and material management requirements.

The MDC system serves as the primary source of information for configuration status accounting at base, command, and AFLC level. Configuration status accounting is used at all levels of management for the following purposes: (1) to identify equipment configuration, (2) to assure accomplishment of time compliance technical orders (TCTOs), (3) to project workload and scheduling requirements, and (4) to provide mechanized historical records for designated equipment. In addition, this program provides AFLC information for validating individual modification requirements. It is also used as an aid in determining kit distribution requirements and TCTO recission dates. Configuration management requirements and procedures are outlined in AFR 65-3, *Configuration Management*, TO 00-20-4, *Configuration Management Systems*. The data for weapon systems and equipment managed under the advanced configuration management systems (ACMS) is used for the purposes described above. It is also used for maintaining accurate configuration status by serial number, for selected high cost as well as mission significant items. This data enables AFLC to provide support with a minimum number of spares. This is done by providing precise removal and replacement predictions and by distributing these spares on a timely basis. The ACMS is also used to maintain information on the equipment, by serial number, and the overall mission capability of the weapon system. This information is a real aid in keeping equipment maintainable and reliable.

Exercises (027):

1. List the benefits that base-level maintenance activities can derive from the MDC system.

2. How is data, collected by the maintenance data collection system, made available to base-level maintenance activities?

3. What are some of the uses of configuration status accounting?

028. Cite accuracy requirement for MDC reporting and the area of responsibility for insuring the accuracy.

Accuracy of MDC Data. Because of the multitude of uses made of the MDC system and the importance of a management information system, it is essential that the data be as accurate as possible. A continuous effort by each individual and by all levels of management is required to make this MDC system pay the greatest dividends.

The effort of data errors varies for different uses. For instances some margin of error can be tolerated when determining inspection intervals for an end item of which there are many in the inventory. However, computing the service life of a high-cost, low-inventory item requires near 100 percent accuracy. Configuration management programs require 100 percent accuracy. As an aid in reducing errors, both the base-level and the AFLC computer programs provide error reports; these reports are then sent to bases and major commands. The report should be employed as management aids—not as instruments to penalize individuals who accidentally caused the errors. The full intent of these error reports is to improve reporting and data utilization.

Edit procedures, to detect errors, are designed to check the validity of all data elements. These procedures are also designed to make cross comparisons between many of the codes; this is done to insure compatibility of data. However, these edit procedures are limited by computer capability, by time, by program complexity, and by the ability to validate entries such as serial numbers. It is, therefore, a responsibility of each performing workcenter supervisor to assure the completeness and accuracy of all forms prior to turning them in for keypunching. This responsibility is for the supervisor of the workcenter, who is identified in block 2 of the AFTO Form 349, Maintenance Data Collection Record. (The AFTO Form 349 is discussed in detail in the following sections of this text.) It is extremely important that the errors are actually corrected, and not doctored to pass edit programs.

Exercises (028):

1. What percent accuracy do configuration management programs require?

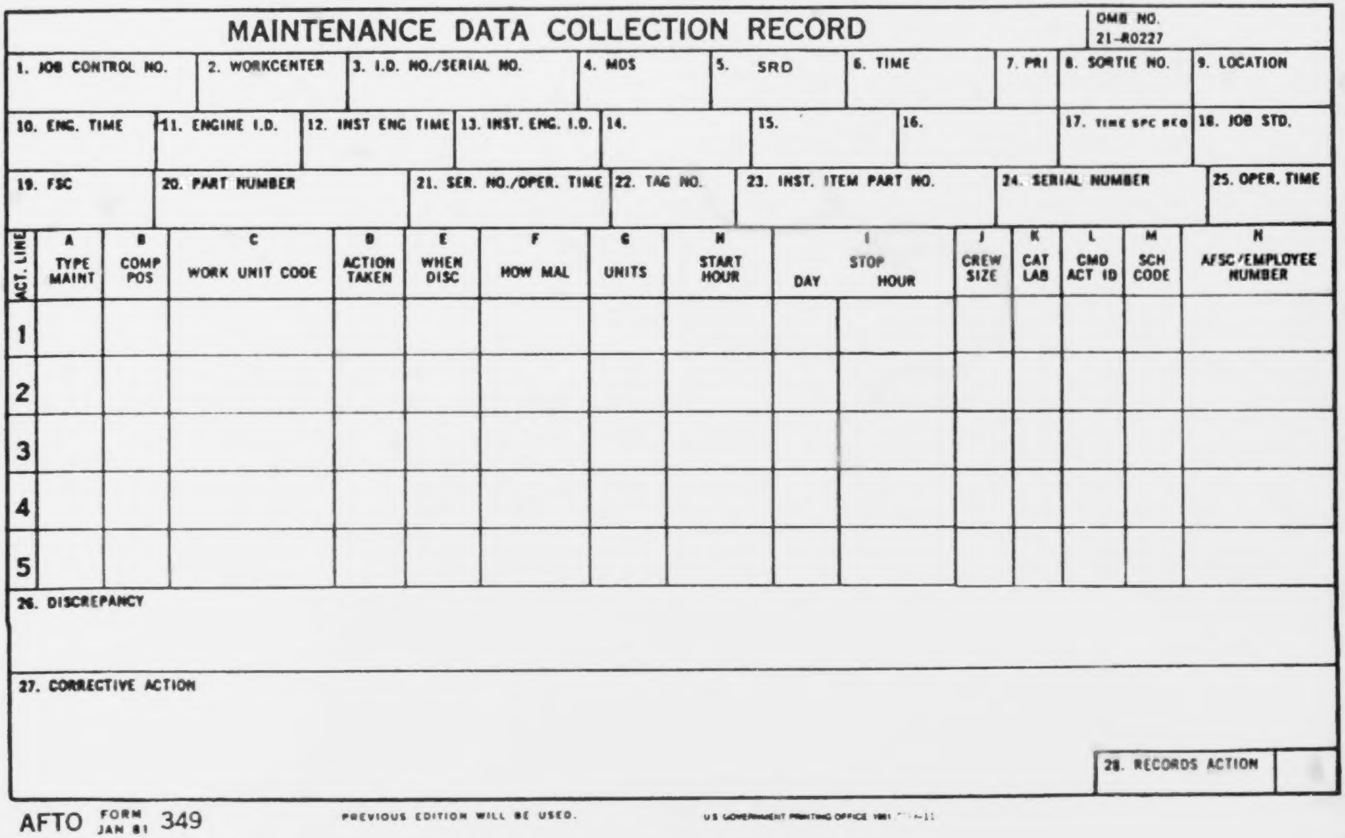
2. Who is primarily responsible for making certain that AFTO Forms 349 are filled out correctly before they are sent forward from the maintenance activity?

029. Distinguish between the MDC forms used to record various types of maintenance.

Maintenance Data Collection System Forms. The AFTO Form 349, Maintenance Data Collection Record, and AFTO Form 350, Reparable Item Processing Tag, are the maintenance data collection systems forms with which you will primarily be concerned. AFTO Form 349 generally is used in two different functional areas of maintenance—support general and TCTO (except PME). Careful completion of these forms is necessary if we are to meet specific reporting requirements. These requirements are outlined in the applicable 00-20-2 series of technical orders.

AFTO Form 349, Maintenance Data Collection Record. The AFTO Form 349 is the principal source document for the MDC system (see fig. 2-2). It is a multipurpose form used to record maintenance actions. The form also serves as a dispatch work monitoring record when used in maintenance or production control activities. A copy of AFTO Form 349 is provided to a specialist as a dispatch notice. It is also used to record the maintenance actions completed in performing the work. This provides a production credit record and an input to the MDC system for subsequent analysis and management use. This type of multipurpose form also keeps the recording burden for maintenance personnel to a minimum.

Notice in figure 2-2 that the AFTO Form 349 provides lines for recording up to five maintenance actions. This feature reduces the number of forms on which basic



MAINTENANCE DATA COLLECTION RECORD

OMB NO. 21-R0227

1. JOB CONTROL NO.	2. WORKCENTER	3. I.D. NO./SERIAL NO.	4. MDS	5. SRD	6. TIME	7. PRI	8. SORTIE NO.	9. LOCATION

10. ENG. TIME	11. ENGINE I.D.	12. INST ENG TIME	13. INST. ENG. I.D.	14.	15.	16.	17. TIME SPC REQ	18. JOB STD.

19. FSC	20. PART NUMBER	21. SER. NO./OPER. TIME	22. TAG NO.	23. INST. ITEM PART NO.	24. SERIAL NUMBER	25. OPER. TIME

ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP DAY	 HOUR	J CREW SIZE	K CAT LAB	L CMD ACT ID	M SCH CODE	N AFSC/EMPLOYEE NUMBER
1															
2															
3															
4															
5															

26. DISCREPANCY

27. CORRECTIVE ACTION

28. RECORDS ACTION ☐

AFTO FORM JAN 81 349 PREVIOUS EDITION WILL BE USED. US GOVERNMENT PRINTING OFFICE 1981 [illegible]-11

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Figure 2-2. AFTO Form 349 (front).

identification must be recorded. Another feature of the MDC system is the use of an identification (ID) number on the AFTO Form 349 for most of the maintenance actions. This reduces the number of handscribed entries and recording errors. The six character ID number is entered in block 3 of the AFTO Form 349. A computer interprets the ID number into the following:

a. Owning workcenter.
b. Equipment serial number.
c. Mission.
d. Design.
e. Series or end item work unit code.
f. Standard reporting designator code for the output products.

For off-equipment maintenance, the ID Number converts to owning workcenter and standard reporting designator code. Detailed instructions for development of ID numbers are contained in AFM 66–267.

AFTO Form 350, Reparable Item Processing Tag. The AFTO Form 350 is shown in figure 2-3. This document is a two-part perforated form that is attached to components removed from equipment end items. The form serves as an identification and status tag. Use of this tag is essential to assure that the status of reparable items can always be identified. This tag is also used to provide a source document; i.e., for information required in completing an AFTO Form 349 on off-equipment (shop) repair actions. It also provides a means for controlling items flowing to and from intermediate maintenance shops. It is the accountability document for items managed under the due-in from maintenance (DIFM) program outlined in TO 00–20–3, IMaintenance Processing of Reparable Property and Repair Cycle Asset Control System. Dates pertaining to the base-level and depot-level repair cycle time are also entered on this form. These dates are used as an aid in determining spare requirements.

Another important aspect of the AFTO Form 350 is that it serves as a source document pertaining to reparable this station (RTS) and not reparable this station (NRTS); it also serves as a source document on condemnation actions for the supply system. This information is then used as an input to the supply computer to identify stockage requirements. Through use of a formula, this information is used to establish base stock levels on recoverable and other selected items. Information pertaining to RTS, NRTS, and condemnations is also forwarded through the supply system to AFLC where it is used to provide data for computing the worldwide spares requirements. The information entered in the supply system does not duplicate and will not match information in the MDC system because the procedures, applicability, and requirements vary widely. Recording procedures for the AFTO Form 350 are outlined in the 00–20–2 series technical orders. (This form also is discussed in detail in a following section.)

Exercises (029):

1. Name the forms you would use generally when reporting on-equipment maintenance.

2. What AFTO forms are used as source documents for the MDC system?

3. How many maintenance actions may be recorded on a single AFTO Form 349?

4. Which AFTO form serves as an identification and status tag?

030. State the procedures for documenting various categories of maintenance actions.

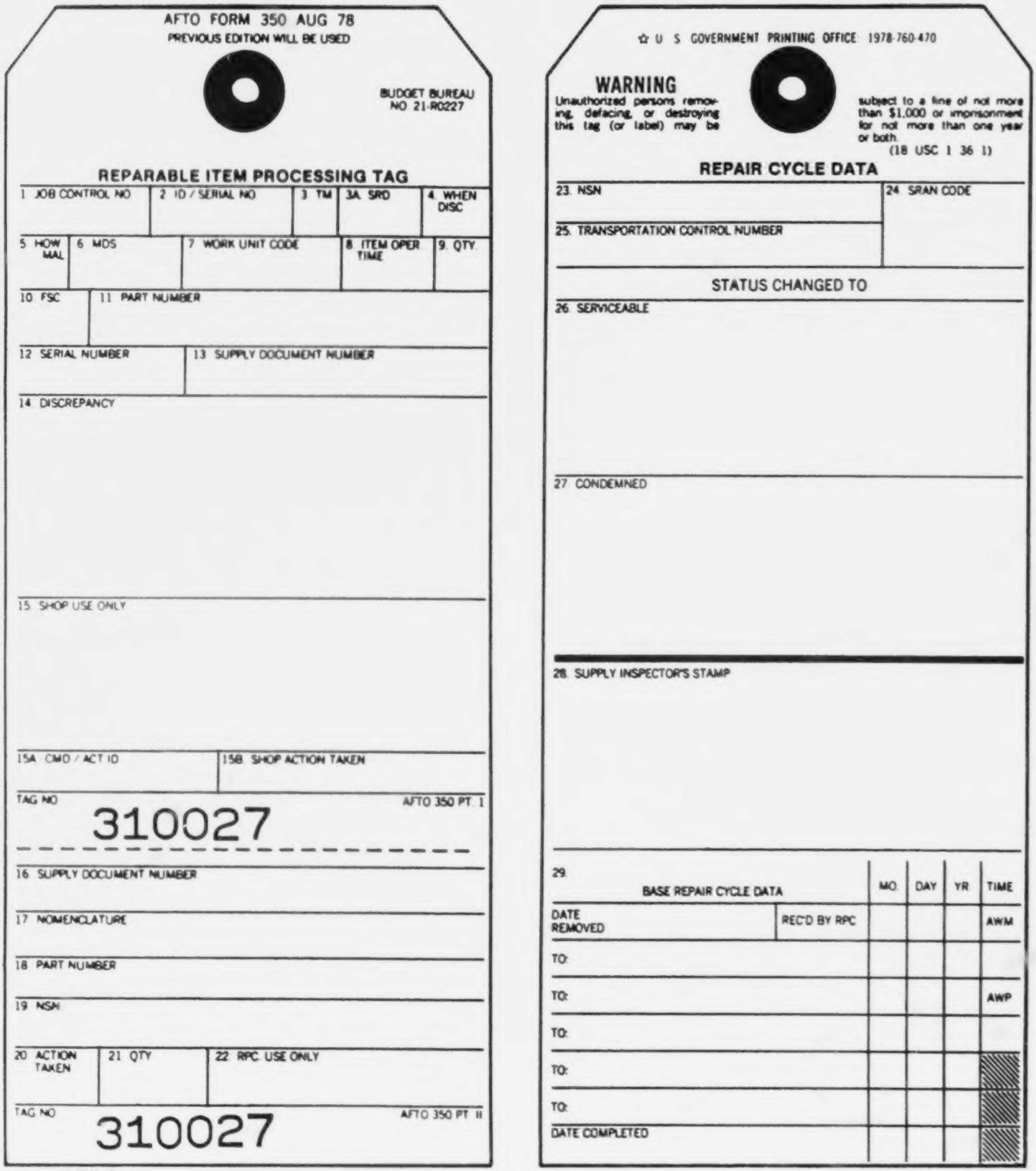
General Recording Procedures for AFTO Forms 349 and 350. As previously mentioned, maintenance accomplished on end items of equipment is recorded on the AFTO Form 349. This form is then processed for keypunching. If the maintenance action involves removal of an item, an AFTO Form 350 is initiated. Any subsequent shop maintenance such as bench check and repair requires another AFTO Form 349 to document the shop maintenance actions.

Maintenance actions accomplished on complete end items of equipment (aircraft, missiles, removed engines, trainers, etc.) are identified as on-equipment work. This primarily consists of (1) support general tasks, (2) inspections, (3) removal and replacement of components, (4) fix-in-place maintenance actions, and (5) accomplishment of modifications. In-shop maintenance actions involving intermediate-level maintenance on removed components is identified as off-equipment maintenance. This primarily consists of (1) bench checks, (2) repair or modification of components and assemblies, and (3) nondestructive inspections. Again refer to figures 2-2 and 2-3 for the following discussions.

For on-equipment work, the primary entries required on AFTO Form 349 are made in block 1 (Job Control Number), block 2 (Workcenter), block 3 (I.D. No./Serial No.), block 6 (Time), block 7 (PRI), block 9 (Location), block 17 (Time Spec Req), block 18 (Job Std.), block 26 (Discrepancy), and columns A through N.

For off-equipment work on removed components, primary entries are required in blocks 1, 2, and 3 or 5; block 19 (FSC); block 20 (Part Number): block 21 (Ser. No./Oper. Time); block 22 (Tag No.); columns A through N; and block 26 (Discrepancy).

Sometimes maintenance is performed on components that are removed for the convenience of making repairs or on components removed and replaced to facilitate other maintenance (FOM). If done immediately, adjacent to the end item of equipment, it is correctly recorded as on-equipment maintenance. When the individual, who removed the component, has to leave the immediate area (defined as out-of-sight), this person must prepare an AFTO Form 350 to identify the status of the removed component.



AFTO FORM 350 AUG 78
PREVIOUS EDITION WILL BE USED

BUDGET BUREAU
NO 21-R0227

REPARABLE ITEM PROCESSING TAG

1 JOB CONTROL NO
2 ID / SERIAL NO
3 TM
3A SRD
4 WHEN DISC
5 HOW MAL
6 MDS
7 WORK UNIT CODE
8 ITEM OPER TIME
9 QTY
10 FSC
11 PART NUMBER
12 SERIAL NUMBER
13 SUPPLY DOCUMENT NUMBER
14 DISCREPANCY
15 SHOP USE ONLY
15A CMD / ACT ID
15B SHOP ACTION TAKEN

TAG NO 310027 AFTO 350 PT I

16 SUPPLY DOCUMENT NUMBER
17 NOMENCLATURE
18 PART NUMBER
19 NSN
20 ACTION TAKEN
21 QTY
22 RPC USE ONLY

TAG NO 310027 AFTO 350 PT II

☆ U S GOVERNMENT PRINTING OFFICE 1978-760-470

WARNING
Unauthorized persons removing, defacing, or destroying this tag (or label) may be subject to a fine of not more than $1,000 or imprisonment for not more than one year or both.
(18 USC 1 36 1)

REPAIR CYCLE DATA

23. NSN
24. SRAN CODE
25. TRANSPORTATION CONTROL NUMBER

STATUS CHANGED TO

26. SERVICEABLE
27. CONDEMNED
28. SUPPLY INSPECTOR'S STAMP

29. BASE REPAIR CYCLE DATA		MO.	DAY	YR	TIME
DATE REMOVED	REC'D BY RPC				AWM
TO:					
TO:					AWP
TO:					
TO:					▨
TO:					▨
DATE COMPLETED					▨

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0-11e

Figure 2-3. AFTO Form 350 (front and back).

In this regard, when personnel from one workcenter removes an item and delivers it to personnel with a different workcenter code maintenance, the latter workcenter records it as off-equipment maintenance.

We previously mentioned that up to five related on-equipment maintenance actions may be reported on a single copy of the AFTO Form 349. These actions must be covered by a single job control number against a single ID number, and accomplished by a single workcenter. If more action lines are required, another AFTO Form 349 containing the same job control number, ID number, and workcenter code is completed and the actions continued. This recording procedure also applies to off-equipment actions; however, on-equipment and off-equipment actions may not be combined on a single copy of the AFTO Form 349.

Assume that a malfunction on a system required the removal of four "black boxes." The removal (or removal and replacement) action for all four black boxes may be recorded on a single AFTO Form 349. However, you use separate line entries in columns A through N if the work unit codes of the black boxes are different. The black boxes could be reported as one entry if the job control number, work unit, action taken, how malfunctioned, and when discovered codes are all the same; then, a unit count of four is entered in column G. A separate AFTO Form 350 must be prepared for each item. Serially controlled and time change items (with an asterisk in the work unit code manual) must be recorded on an individual basis; i.e., only one item per AFTO Form 349 or 350. Separate line entries in columns A through N are also required whenever the crew size for a specific job changes or any delay exceeds 15 minutes.

The form entry requirements in columns A through N of the AFTO Form 349 for time compliance technical order (TCTO) reporting are the same as those required for other maintenance actions with one exception: the recording of the TCTO data code. The first five digits of the TCTO data code number are recorded in column C; the sixth digit entered in column D; and the seventh digit entered in column E.

Entries in block 3 (Serial No.), block 4 (Mission, Design, Series), and block 5 (Standard Reporting Designator Code) for on-equipment work are made only for transient aircraft and end items of equipment (except engines) for which ID numbers have been assigned. The entries in these blocks and the resulting keypunching of this information in the allocated card columns overrides the computer program feature for converting the ID number to the weapon system/equipment and item identification. Entries in these blocks also eliminate the computer's ability to identify the owning workcenter. Therefore, strict compliance with recording requirements for serial number, mission/design/series (MDS), and equipment classification code entries must be adhered to for elimination of unwarranted expenditures of recording and keypunching effort.

An entry in block 6 (Time) is required only when reporting the removal and replacement of engines, aircraft tires and wheels, and time change or serially controlled items. When applicable, enter the equipment time to the nearest whole hour for the equipment identified in block 3.

There is one final bit of information that we want to give before going on to the next subject. The AFTO Form 349 does not contain a symbol block. Therefore, it is mandatory that all red X and circled red X discrepancies, including those discovered and corrected during schedule inspection, be recorded on the AFTO Form 781A, Maintenance Discrepancy and Work Document. This is to document the "corrected by" and "inspected by" signatures. All uncleared discrepancies, regardless of symbol, must also be recorded on the AFTO Form 781A.

Exercises (030):

1. What blocks in the AFTO Form 349 are used for primary entries to document work?

2. You are repairing a component that is installed on an aircraft. You decide that it would be more convenient to remove the component to repair it. After repair, you reinstall the component. Is this repair action considered on-equipment maintenance? Explain.

3. How should you record both on-equipment and off-equipment maintenance actions?

4. Assuming that a malfunctioning system on an aircraft required you to remove and replace two identical amplifiers, would separate AFTO Form 349 entries be required for each amplifier? Explain.

5. Under what conditions are entries for on-equipment work made in blocks 3, 4, and 5 of the AFTO Form 349?

6. What AFTO form do you use to record all uncleared aircraft discrepancies?

031. State and explain actions for preparing AFTO Form 349.

Use of AFTO Form 349 for Maintenance Documentation. You can see in figure 2-2 that the AFTO Form 349 contains 28 blocks on the front side. The form also contains columns A through N. No one maintenance operation requires the use of every block of this form.

Therefore, it is not necessary that each block be filled in for every maintenance operation. When the form is given to you directing the performance of a specific job, certain blocks will already be filled in. You are responsible for making entries in other blocks on the form as you proceed with your work assignment. It is possible that you will be required to initiate different forms as a result of your work. To initiate and transcribe entries to the new forms, you need a general knowledge of the type of information required in each block. Remember, the 00–20–2 series technical orders provide governing directives on how to complete these applicable forms. Now refer to figure 2-2 as we discuss the various blocks of AFTO Form 349.

Job control number. A new Job Control No. (JCN) in block 1 is assigned to each unrelated discrepancy by Job Control. All documentations of action taken to correct the discrepancy, whether on the flight line or in the shops, are considered part of the job, and therefore carry the same job control number.

Workcenter. The Workcenter, block 2, always contains the identifier of the workcenter of the person performing the task. If two workcenters are involved in the action, two forms are required; one form for each workcenter. This workcenter designator is the standard five-digit USAF workcenter code established under provisions of TO 00–20–2, *Maintenance Data Collection System*.

I.D. No./Serial No. The I.D. No./Serial No., block 3, is a six-character identifier assigned and used to identify the type of equipment on which work was performed or from which an item was removed. This character (J), of a six-unit alphanumerical code (such as JA 4235) is the first character of the owning workcenter code. The second character (A) is the first letter of the equipment classification code. The last four digits are normally the last four numbers of the equipment's serial number. The computer will convert this number to the appropriate mission, design, series, full serial number, and owning workcenter.

MDS. For on-equipment work, the Mission, Design, Series (MDS), block 4, is used when ID Numbers are not assigned. In this case, the complete mission, design, and series is entered in the block.

SRD. The Standard Reporting Designator Code (SRD) is entered in block 5. The SRD code consists of three characters, and is normally used when no entry is recorded in block 3.

Time. An entry in block 6 (Time) is required only when reporting the removal and replacement of engines, aircraft tires and wheels, and time change or serially controlled items. When applicable, enter the equipment time to the nearest whole hour for the equipment identified in block 3.

PRI. The priority (PRI) of the work will be entered in block 7 by Job Control or by the agency preparing the form. Priorities are determined by Job Control to identify those units of work which are of the greatest immediate need to the organization.

Sortie No./location. At the present time, no entry is made in block 8, Sortie No. The location where the job is to be performed is entered in block 9, Location; however, this is only when the AFTO Form 349 is used as a dispatch document or form—otherwise, this block is left blank.

Blocks 10 through 13 are used only for the documentation of aircraft or missile engine changes.

Blocks 14 and 15 are used at the discretion of local management.

Ten Sup/Act ID. Block 16 has been provided as Tenant Supply Activity Identifier, on an optional basis. You enter a two-digit code to identify both on-equipment and off-equipment work accomplished for a tenant organization. The two-digit identifier will have to be developed by local management and used when work is performed to support tenant units. It is desired to document only on-equipment work in support of a tenant. This can be accomplished through the ID number, thus freeing the two card columns for other local usage as directed.

Time Spc Req. The time the mechanic is scheduled to begin work is entered in block 17, Time Specialist Required. An entry is required in this block only if the form is used for dispatch work.

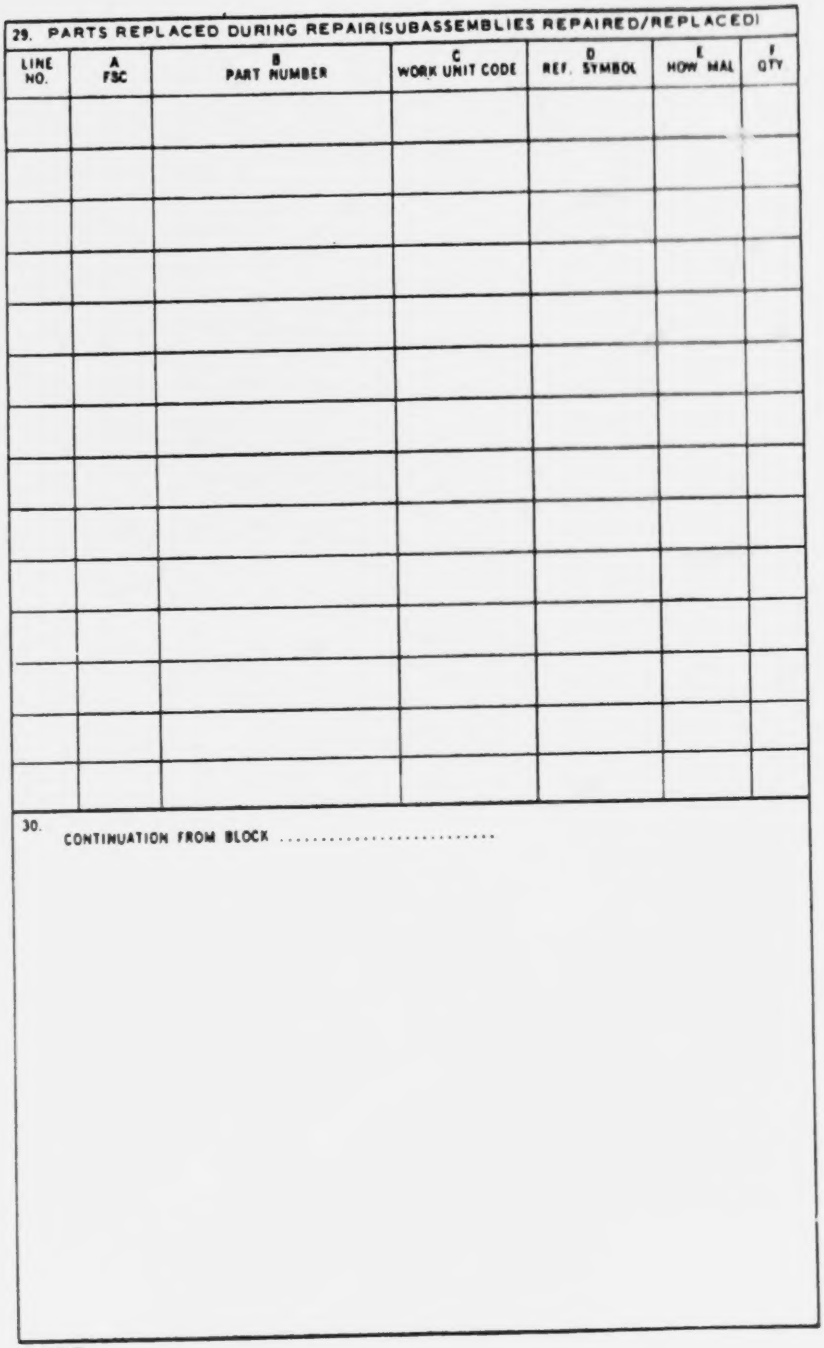
Job Std. The job standard entries in block 18 are made for preplanned and job-control directed tasks that have job standards or averages developed. In the case of jobs for which standards or averages have not been developed, an estimate of the time required for completion is entered.

FSC and Part Number (Federal Stock Class and Part Number). For off-equipment work done under an advanced configuration management system (ACMS), your enter the national supply class (NSC) code for the item being repaired in block 19. You enter the part number of the item being repaired in block 20. First preference is to use the manufacturer's part number of the complete identification as it appears on the equipment data plate. You must include all dashes and slashes included in the number. For those items that do not have part numbers, you enter the national item identification number (NIIN), which is the last 9 digits of the national stock number. No entry is made for items that are locally manufactured and not stocklisted. The NIIN must be suffixed with a two-digit identifier of the manufacturer's name.

Ser. No./Oper. Time. Block 21 is used for two different types of entries. When an entry is made, the unused portion of the Ser. No./Oper. Time would be struck out; this signifies that the entry is actually the serial number. The serial number of time-significant or serially controlled items, which are removed, is then entered in block 21. If the serial number exceeds 10 characters, enter only the last 10 characters. For off-equipment work involving time change items and items that have an elapsed time indicator (ETI) installed, enter the item operating time in this block. (You should check policies for possible changes.)

Tag No. When articles managed under ACMS are removed, the last three digits of the AFTO Form 350 tag number are entered in block 22 of AFTO Form 349. This is also true whenever entries are made in block 29 (of AFTO Form 349) because of component repairs (fig. 2-4).

Other entries. /n Other entries. Entries are required in blocks 23, 24, and 25 of AFTO Form 349 only for time change items and items controlled under ACMS. We mentioned earlier that the front center part of the 349 form (fig. 2-2) is divided into five action lines. Each line is numbered and further divided into a vertical column. The



29. PARTS REPLACED DURING REPAIR(SUBASSEMBLIES REPAIRED/REPLACED)

LINE NO.	A FSC	B PART NUMBER	C WORK UNIT CODE	D REF. SYMBOL	E HOW MAL	F QTY

30.

CONTINUATION FROM BLOCK ....

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Figure 2-4. AFTO Form 349 (back).

lines have been numbered so that when a discrepancy requiring a bit-and-piece entry in block 29 (fig. 2-4) is made, the entry can be identified by the action line number. The entry in column A, Type Maint (fig. 2-2), is the single-digit-type work identifier. Aircraft electrical personnel do not use column B.

The work unit code entry in column C (of AFTO Form 349) is a five-digit code used to identify the equipment being worked on. The first two digits identify the system. The next three digits identify the subsystem and the specific components. You would enter the work unit code (WUC) from the applicable WUC (-06 TO) manual for the equipment being repaired. When the AFTO Form 349 is used for documenting any work done for TCTO, the first five digits of the seven-digit TCTO data code are entered in column C and one digit in columns D and e, respectively.

The Action Taken, When Disc, and How Mal blocks are used in conjunction with the work unit code to identify a complete unit of work. These codes are provided in directive literature, which you will have available where you work. You enter, in column D, the Action Taken code that identifies the action taken against the item. In column E, you enter the appropriate When Disc code to identify when the defect or need for the maintenance action was discovered. The entry that identifies the How Mal or no-defect code which best describes the nature of the malfunction or action required on the item is entered in column F.

In column G, Units, you enter the number of times that action identified in column D was taken against the item identified in column C.

In column H (Start Hour, to the nearest 5 minutes) enter the hours that the job identified on this line started.

Enter the Julian day and hours (to the nearest 5 minutes) in column I (Stop/Day/Hour) that the job on this line stopped. For example, if a person works from 0700 to 1200, eats lunch from 1200 to 1300, and resumes work at 1300, two sepárate entries are required.

The number of persons involved in the job, identified on that line, is entered in column J, Crew Size. If workers are added to a job or removed from it, that line entry must be closed out with zero units completed, and a new line entry initiated for the proper number of personnel involved.

In column K, an entry is required to identify the makeup of the crew. If the crewmembers are all military or all civilian, only one entry line is used. But if the crew is partly military and partly civilian, a line entry for each category is required.

An entry in column L is required only when there is no entry in block 3.

A two-position command code is required in column M when work is done on transient aircraft that have no I.D. No./Serial No.

You enter the five-digit, locally assigned Employee Number in column N. If more than one individual participates in the work described on this line, the senior person's number, whether or not this person is the supervisor, is entered in this column. The Employee Number is constructed from the first letter of this person's last name and the last four digits of the individual's Social Security Account Number (SSAN). If duplicates occur, one number is changed to eliminate the duplication.

Enter a complete description of the discrepancy or work to be performed in block 26, Discrepancy. For on-equipment minor fix and support general maintenance, no entries are required in block 26. In this case, the entries in columns A through N are enough to identify the work. Assume that the form is initiated by the records unit for a scheduled accessory replacement. If an entry is made either as scheduled or as premature due to failure, the accrued time, also called the elapsed time indicator (ETI), is recorded in block 26. This is accessory time and not aircraft time. When removal and replacement of a reparable component are involved and a demand was made on the supply system, enter the document number assigned by supply for the replacement of an item(s) or the requisition number in block 26.

In block 27, Corrective Action, enter a brief but specific description of the work completed to correct the discrepancy. An entry is not required for on-equipment support general activities (servicing with oil, hydraulic fluid, etc.) or a minor fix. If an operational check cannot be made immediately after completing the required maintenance, the line entry is closed out. A statement of the required functional check is entered in this block. A new line entry must be completed for the functional check when it is accomplished.

A checkmark is placed in block 28, Records Action, to distinguish maintenance actions that affect the historical records of an end item. If the records section initiates the form for a scheduled components replacement or a TCTO, a checkmark is made to allow the form to be returned to the records section. Unscheduled time-significant replacements require the person completing the action to check block 28. This signifies that the action affects the historical records of the end item.

You enter the identification of components and parts consumed in making repairs in block 29, Parts Replaced During Repairs (reverse side of AFTO Form 349). Entries are required for nonreparable/nonrecoverable items. The consumption of common hardware items such as nuts, bolts, screws, washers, safety wire, clamps, common gasket and seals, hose connections, etc., are not reported.

Block 30, Continuation Form Block (also on reverse side) provides space for continuation of any other block of the AFTO Form 349.

Exercises (031):

1. Who assigns the job control number?

2. A maintenance action requires the services of two separate workcenters. Can the maintenance be documented on a single AFTO Form 349? Explain.

3. When the prescribing document is the AFTO Form 349, what identifies the particular item of equipment on which work is to be performed?

4. Who supplies the priority which is posted in block 7 of the AFTO Form 349?

5. Under what condition is block 9 of the AFTO 349 used?

6. What does the number 0900 entered in block 17 of the AFTO Form 349 indicate?

7. If a job standard has not been established for a particular task, what entry is made in block 18 of the AFTO Form 349?

8. Under what condition is the NIIN (national item identification number) entered in block 20 of the AFTO Form 349?

9. What block on the AFTO Form 349 identifies the specific unit on which work is being performed?

10. What does 0130910 in block I of the AFTO Form 349 indicate?

11. Assume that two specialists from the same shop participate in a maintenance task. Which specialist's "employee number" is entered in column N of the AFTO Form 349?

12. A repair job was completed in the morning. However, the required operational checkout of the job cannot be completed until 1400 hours. What entries must you make in the AFTO Form 349?

032. Determine the correct entires to put on AFTO Form 350.

Use of AFTO Form 350 for Maintenance Documentation. Most of the information required for this form is found in the corresponding blocks of AFTO Form 349. Refer to figure 2-3 as we discuss the entries for the various blocks on AFTO Form 350.

You enter the job control number from AFTO Form 349 in block 1 of AFTO Form 350. If a component is broken down into subassemblies, each subassembly must be tagged with a separate AFTO Form 350 bearing the original job control number for off-equipment repair.

You enter the ID number from block 3 of AFTO Form 349 in block 2 of AFTO Form 350.

Enter the Type Maintenance (TM) code in block 3, and the Standard Reporting Designator code in block 3a.

The When Disc and How Mal codes from columns E and F of AFTO Form 349 are entered in blocks 4 and 5, respectively, of AFTO Form 350.

No entry is required in block 6, MDS, except for transient aircraft maintenance.

In block 7 of AFTO FOrm 350, enter the applicable work unit code for the item removed. This is the code that was entered in column C of AFTO Form 349.

If the item is a time change or a serially controlled item, the time accrued on the item is entered in block 8, Item Oper. Time.

In block 9, QTY, you enter the number of like items being forwarded for processing. You must fill out a separate AFTO Form 350 for each time change or serially controlled item.

The Federal Supply Class code for the removed items is entered in block 10, FSC.

The manufacturer's part number is the first preference for entry in block 11, Part Number. If no part number is assigned, the complete identification as it appears on the data plate is entered in block 11. In writing this number into the block, all dashes and slashes must be entered. For items that do not have a part number, the NIIN is entered.

For time-significant and serially controlled item of equipment (marked with an asterisk in the individual equipment work unit code manual) the serial number of the item is entered in block 12, Serial Number. If the serial number exceeds 10 digits, enter only the last 10 digits.

When a demand has been placed on the supply system for a like item as a replacement, the document number is entered in block 13, Supply Document Number.

A brief but special description of the malfunction is entered in block 14, Discrepancy. For items having a calendar and/or time warranty, an entry is required to reflect the date and time of removal and the date and time of installation, as well as a brief but accurate statement as to the reason for removal.

A brief description of the work completed on the part is entered in block 15, Shop Use Only, if the item was made serviceable by replacing a component part or repairing connections. If the item is not reparable at your station, print or stamp NRTS (not reparable this station), and include the NRTS code in this block. If NRTS code 1 is used, the authority for declaring the item NRTS must be given. Part II of the front side of the AFTO Form 350 is to be completed by Production Control/Reparable Processing Center (RPC). It will be detached and retained by that activity as a record copy until the item is returned from the repair shop. The entries required on the front side of the 350 are merely copied from similar entries on the top-front side of the 349. Thus, there is no need to discuss them again, with the exception of blocks 20 and 22 on the 350. When the repair work is completed by the shop or the item is declared NRTS, and the paperwork (AFTO Form 349) is forwarded from the repair activity, the Action Taken code from column D of the 349 is entered in block 20 of the 350. Block 22, RPC Use Only, is to be used locally (as necessary) by Production Control/Reparable Processing Center (RPC).

The backside of the AFTO Form 350 contains more spaces, some of which will concern you; however, others will be of no interest to you. Again refer to the backside of AFTO Form 350, shown in figure 2-3.

The national stock number (the same as in block 19) (front side of 350) is entered in block 23, NSN.

When a component is determined to be in NRTS status, the base stock record account number (SRAN) code is recorded or stamped in block 24 by the shop concerned or by RPC.

Block 25 is for use by supply only. You do not make any entries in this space.

Block 26, Serviceable, entries are made by the agency responsible for returning the item to a serviceable status. A stamp or signature and a dated entry is acceptable.

No entries are made in block 27, Condemned.

Block 28, Supply Inspector's Stamp, is reserved for supply use only.

Reparable processing center is responsible for completing the entries made in block 29, Base Repair Cycle Data. This is the back side of Part II of the Form 350. Entries are made in this block to reflect the date on which the item was received by RPC and to indicate status changes for the unit. Examples: TO Shop, TO AWM (awaiting maintenance), TO AWP (awaiting parts), with corresponding dates in order to make possible the computation of "AWM Time" and "AWP Time." When computing the AWM and/or AWP time, the status of the item at the beginning of the day will be the chargeable status for that day, regardless of the number of status changes occurring in that assigned day.

Exercises (032):

1. From what source does most of the information come that is entered in the AFTO Form 350?

2. You are filling out an AFTO Form 350 and discover that the part you are identifying has no part number nor data plate. What do you enter in block 11 of the form?

3. Under what condition would an entry be made in block 13 of the AFTO Form 350?

4. If you repair an item by replacing a component, where on the AFTO Form 350 do you make an entry telling of this action?

5. Who is responsible for making an entry in block 26 on the AFTO Form 350?

033. State the effect of specified situations on the job control number.

Job Control Number (JCN). The job control number provides a means to tie together all on- and off-equipment actions taken whether it be a discrepancy, an inspection, or a TCTO. It also includes man-hours expended and parts consumed. Every action taken that is related to a job, regardless of workcenter, time, or place, carries the same job control number that was originally assigned to the job. This procedure is necessary to permit control of all related actions. It also provides the capability to tie them together in data systems to identify the total job for analysis purposes. For given work situations, Job Control may assign certain job control numbers to identify the following work situations: (1) equipment discrepancies, (2) TCTO and time change requirements, (3) inspections, and (4) support general work other than inspections.

The first three characters of the JCN constitute a number for the Julian date such as 041 for 10 February. The last four digits are used to identify jobs. They normally consist of a daily job sequence number such as 0001 for the first job of the day. Using the cited examples, the JCN would be 0410001.

Job control number for equipment discrepancies. Discrepancies pertain to those parts or end items of equipment that require corrective maintenance due to failures, defects, damage, or similar conditions. The JCN is important in the control and analysis of such discrepancies. Equipment discrepancies frequently involve unscheduled maintenance.

With the exception of major inspections, each unrelated discrepancy has a separate JCN assigned. Use a given JCN for all subsequent maintenance actions to correct the discrepancy on a particular item. When two unrelated discrepancies are corrected by an individual or a team on the same equipment, use two different JCNs.

An item or a group of like items, are received from supply and which require a bench check or inspection for serviceability, have a single JCN assigned. Any discrepancies discovered through this process (bench check or serviceability inspection) are normally recorded using the single JCN assigned. An item that is installed after being withdrawn from supply stock is recorded by using the original JCN assigned to that job. If an item is withdrawn from supply for installation and is determined to be unserviceable, a new JCN is assigned for the discrepancy on that item.

Job control numbers for TCTO and time change requirements. Accomplishment of time compliance technical orders (TCTOs) and removal and replacement of items, due to time change requirements, have JCNs assigned in accordance with the following:

a. Each individual on-equipment TCTO has a JCN assigned for the end item of equipment being modified.

b. Each commodity series TCTO has a single JCN assigned which is used for recording compliance on all spares. Accomplishment of commodity series TCTOs while the item is installed on an end item of equipment requires a separate JCN for each end item to be modified.

c. Each replacement of a time change item due to expiration of its time, number of events, etc., has a JCN assigned. Removal of each time change item prior to expiration criteria has a JCN assigned.

d. Accomplishment of TCTOs during an inspection are recorded using individual JCNs.

Job control numbers for inspections. Discrepancies discovered during major inspections are considered as part of the inspection, and they are recorded by using the JCN for the inspection. However, discrepancies discovered prior to an inspection but corrected during an inspection are recorded by the original JCN for the discrepancy. A JCN is assigned for the look phase of daily, preflight, and basic postflight inspections. Each discrepancy discovered during these inspections has a separate JCN assigned.

Job control numbers for supporting general work other than inspections. Support of general work other than inspections is accounted for by using a JCN assigned each day to cover categories of work on all equipment with the same end item identification. Work that continues into the next day retains the same JCN. An alternate method is to assign a JCN to each serially numbered end item for each day.

Exercises (033):

1. What date and job control number does 0970431 indicate? (Consider a nonleap year.)

2. Name the four basic categories of work.

3. You are working on a maintenance team on a particular aircraft and find two unrelated discrepancies. You fix one and a fellow team member fixes the other. The last job control number used is ---029. What two new JCN number(s) would be assigned?

4. You are bench-checking 20 identical components just received from supply. How many JCNs would be used for bench-checking the components?

5. You accomplish a TCTO on an aircraft component during a major inspection. Would the TCTO work be documented under the inspections JCN or under the time-compliance JCN?

6. During a major inspection you discover a defective component. Would the defective component be documented under the inspection JCN, or would a new JCN be assigned?

7. You are doing general support work other than inspections. This work takes 2 days. Does this second day's maintenance require a new JCN?

034. State the purpose and function of the standard reporting designator code.

Standard Reporting Designator Codes. Standard reporting designator codes (SRD) are made up of three characters and are used to identify Air Force equipment such as aircraft and simulators. These codes are used for reporting and control procedures. An example of such a code is AF7. The first letter of the code designates the general type of equipment. The last two characters designate the specific type of equipment. In our example, the A designates that the equipment falls under the general category of aircraft. The F7 signifies that it is an F-111F aircraft. The same designation technique is applied to identifying all aircraft, missiles, ground electronic systems, and aerospace ground equipment (AGE) used throughout the Air Force. Codes for all Air Force equipment can be found in the AFR 300-4 series, *Standard Elements and Codes*, and TO 00-20-2 attachments.

Exercises (034):

1. What is the purpose of standard reporting designator codes?

2. State the function of the two parts making up the SRD.

035. Differentiate among the types of reports that are prepared from AFTO Forms 349.

MDC System Processed Reports. As every maintenance task is accomplished, each unit of work is recorded on the AFTO Form 349, as previously discussed. These forms are then collected and the information is keypunched on data cards, which can be run through data automation's equipment. Maintenance data collection reports are then made by machine-processing the punch cards. The results of the processed punch cards are transcribed to various types of maintenance data reports. Daily runs of the punch cards result in the daily production report. These same cards are accumulated, sorted again, and rerun to provide the monthly production summary, as well as various other monthly reports. Different "sorts" (sorting sequence) are used to provide the different reports. For maintenance units that do not have a local data automation activity available, the maintenance data forms are submitted semimonthly to a parent command, which arranges for the processing. This is especially common at overseas stations.

Daily production report. The daily production report provides workload and production information on a daily basis for the lower level maintenance managers. This report must be checked closely for accuracy by workcenter supervisors so that any errors may be corrected before they are included in other maintenance data reports, or before incorrect information is sent to AFLC.

Semimonthly and monthly production summaries (reports). The semimonthly report is for the first half of the month. The monthly report is a compilation of the whole month's maintenance data reporting. These reports are used for workload planning and for surveillance over work performed. Adherence to monthly production schedules may also be checked.

Monthly work order summary. This is a listing of direct labor hours expended and units produced against each work order for the month. Each work order represents a certain type of work on a certain type of equipment. The report is divided into two parts. Part I is for on-equipment maintenance, and Part II is for shop or off-equipment maintenance.

System and component discrepancy report. This is a monthly, two-part report used to analyze discrepancies occurring on equipment. The report is used to identify components that fail frequently, when they fail, repairs required, and the amount of labor expended on each discrepancy. Part I is for on-equipment work, and Part II is for shop or off-equipment work. In addition to the above, there are several other reports that list malfunction information. However, the reports discussed are the most commonly used at the workcenter level.

Exercises (035):

1. How should units without local data service available obtain processing of their AFTQ Forms 349 from maintenance units?

2. Give the intended use of a daily production report.

3. Tell which two types of maintenance reports are used primarily for workload planning and checking adherence to monthly production schedules?

4. What is the purpose of the monthly work order summary?

5. Which maintenance data report should you use to analyze discrepancies occurring on equipment?

036. Cite how a supervisor may use MDC reports.

Improve Methods at Local Levels. By consulting the maintenance data collection reports, the supervisor can determine which tasks are requiring too many man-hours to accomplish. From past experience, the supervisor knows the number of hours normally required for each task. When only a few tasks appear to be taking too long, these may be overlooked. However, when several such tasks coded to one system are overdue, the supervisor may decide there is a need for additional training.

At squadron level, one of the most useful records that can be used for improving work methods is the AFTO Form 95, Significant Historical Data. This form gives the past history of the aircraft and is kept at the analysis section. Here the data is compiled from maintenance information furnished by both the flight line and the repair sections. For example, there may be times that the flight line has not been able to find the reported malfunction. Therefore, flight-line personnel sign it off as, "could not duplicate" (CND). If several of these CNDs show up on the historical report, the analysis section must alert the supervisor of a malfunction that is not being repaired. Another example occurs when the flight line repairs the aircraft by replacing a component. However, shop personnel CNDs the removed component that is replaced. If this component has a history of failures it should be very closely analyzed to determine the problem.

Exercises (036):

1. Were a supervisor to use the maintenance data collection reports to improve methods, what item of the reports might be of use?

2. Name the section that may alert the shop supervisor that a malfunction is not being repaired properly.

3. What is the most useful resource of squadron level for iomproving work methods?

037. Cite the types of maintenance performed by aircraft electrical systems specialists.

Types of Maintenance. As we discussed the maintenance data collection system, we indicated that specific types of maintenance performed are recorded on the AFTO Forms 349 and 350. However, we did not define the types of maintenance. You will need this information because it plays an important function in proper coding of your AFTO Forms 349 and 350.

Unscheduled maintenance. Unscheduled maintenance is maintenance that is not planned. Examples are malfunctions discovered by aircraft personnel, the crew chief, and other maintenance personnel, all of whom can generate maintenance writeups.

Scheduled maintenance. Scheduled maintenance is a job that can be planned in advance. For example, TCTOs, loading aircraft with bombs and mission tapes, and washing of the aircraft can all be planned ahead of time.

Exercises (037):

1. During the postflight inspection, the crew chief discovered a malfunction that had tob e repaired. What type of maintenance would the repair task be?

2. Who may generate unscheduled maintenance writeups?

3. What types of tasks are normally completed during scheduled maintenance?

038. Differentiate among the types of status tags by purpose and title.

Status Tags and Labels. When we think of status tags we should think of the color of the tags or labels. By recognizing the color, you can determine the status of equipment at a glance. There are three basic colors: YELLOW (serviceable), GREEN (unserviceable reparable), and RED (unserviceable condemned). These are all Department of Defense (DD) forms. Their numbers are listed below:

- DD Form 1574, Serviceable Tag—Materiel (yellow).
- DD Form 1574-1, Serviceable Label—Materiel (yellow).
- DD Form 1577-2, Unserviceable (Reparable) Tag Materiel (green).
- DD Form 1577-3, Unserviceable (Reparable) Label Materiel (green).
- DD Form 1577, Unserviceable (Condemned) Tag Materiel (red).
- DD Form 1577-1, Unserviceable (Condemned) Label-Materiel (red).

In addition to those listed, there is the AFTO Form 114, Materiel Deficiency Exhibit. This tag must be used in accordance with procedures ourlied in TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System*.

Another condition tag which we discussed earlier is the AFTO Form 350, Reparable Item Processing Tag. This form is the most widely used tag. It is used to identify all parts in the shop. There will also be times when you have to remove equipment to facilitate other maintenance (FOM). This AFTO Form 350 tag is attached with the information taken from the AFTO Form 349, as discussed earlier in the text, just as if it were going into the shop for repairs. One exception is that in the discrepancy block, we place three large letters: FOM (facilitate other maintenance). This allows the part to remain in the shop without a document number on the tag. The AFTO Form 350 tag must always be attached to units going in for repairs and the condition of the unit or component should be indicated.

Colored tags on containers being received from supply or depot are normally of interest to personnel in the shop complex. In case you receive a part in the shop and there are two different types of tags attached, such as a yellow and green tag; take no chances, have the unit bench checked before it is used.

Exercises (038):

1. Which status label is normally attached to the outside of the box containing a serviceable component received from supply?

2. What is the condition of a component bearing a green tag or label?

3. Which tag is attached to any component within the shop complex?

4. When sending a component to the repair shop, which status tag must be attached?

5. What is the purpose of the status tags?

6. Match the status tags in column A with their titles in column B.

Column A	*Column B*
____ (1) DD Form 1577-2 (green).	a. Serviceable Tag—Materiel.
____ (2) DD Form 1577 (red).	b. Unserviceable (Reparable) Tag Materiel.
____ (3) DD Form 1574 (yellow).	c. Unserviceable (Condemned) Tag Materiel.

039. Cite how materiel received from supply should be packaged and state why.

Control of Materiel. We discussed a few areas of control and documentation of tags in other sections of the CDC, now we will tie these facts together for you.

When you receive a component from supply, it should be packed in a reuseable container. These reuseable containers cost money to design and to build, so do not throw them away as they will be needed later on. Remove the component and store the container in an out-of-the-way area until it is needed again. Also, save the paperwork that comes with the material. Assuming that you have installed the new component, you should have the reparable item to turn in. Before you can turn it in to the reparable processing center (RPC), you have paperwork to prepare. You must have the AFTO Form 350 filled out. With the AFTO Form 350 tag properly filled out, you are ready to attach it to the reparable component. Place the component in a reusable container and, in so doing, gain the full protection from the packing. Even if the RPC is across the hall, that would be no excuse for poor packing. With the reusable container, the reparable component, and the paperwork from supply in hand, go to the RPC section. There the individual on duty will check the AFTO Form 350 tag, and open the box to check the serial number and see that all the documentation agrees. If satisfied, the individual on duty will sign for the item. This fact is very important. Until the item is signed for, the individual on duty has not assumed the responsibility nor the accountability for the item. So far, you have done everything required; but what about that paperwork you have inhand? Your supervisor will want to save it in a special file and will show you how to file it correctly. This insures proof of the turn-in, in case the part is lost. This is the normal procedure for turning in parts or material.

The Air Force has bought a limited supply of spare parts as replacements. There may be times when we have used all the serviceable units on base. In case of shortage, an unserviceable unit must be repaired and reinstalled. In this case, the remove, repair, and reinstallation program is put to use.

Exercises (039):

1. How should parts being received from supply be packaged?

2. What supply unit should you deal with to turn in components for repair?

3. Why should the component being turned in be protected at all times?

4. Cite the method by which responsibility and accountability is assumed by the shop, and again by the RPC section.

5. When may you use the remove, repair, and reinstall program?

6. What are the requirements for turning in components to RPC?

040. Cite the categories used for reporting various types of materiel deficiencies.

USAF Materiel Deficiency Reporting and Investigating System. The maintenance data collection system is the primary source of data collection and is, therefore, the principal source of materiel deficiency information. However, because this system does not cover all deficiencies that need to be reported, there is a need for other reporting procedures. These procedures are outlined in TO 00–35D–54, *USAF Materiel Deficiency Reporting and Investigating System*. The reporting procedures that you will use are classified into category I and category II reports.

Category I report. A category I report covers emergency conditions pertaining to safety on all types of equipment. Such reports are submitted by electrical transmission to the air logistic center (ALC), where they generate investigation projects. These projects are given the highest priority available. They require continuous (around-the-clock) action for resolution.

Category II report. A category II report is used for nonwork-unit-coded items that have design and maintenance materiel deficiencies. The deficiency of such items does not have a safety impact; but if left uncorrected, it would:

a. Create a safety hazard.
b. Have a negative effect on operational efficiency.
c. Reduce tactical ability or tactical support ability.
d. Reduce the operational life or general service utilization of equipment.
e. Create economic burdens (in terms of both manpower and money).

A category II report is also used to report materiel deficiencies for items not conforming with applicable specifications, drawings, or standards, as well as items having errors in workmanship incurred during manufacture, repair, modification, or maintenance.

Category II reports are submitted to ALC by mail on Standard Form 368, Quality Deficiency Report. All defects submitted on this report must be identified as critical, major, or minor, as specified in TO 00–35D–54.

Exercises (040):

1. You find that a construction feature of your aircraft could result, if not corrected, in serious injury to a mechanic. What materiel deficiency report should you use to report this condition?

2. Several new aircraft have been received by your organization. After several operational checks, you find that they will not maintain a preflight condition for which they were designed. You check the schematic diagram for the particular system and find that the circuit was not designed to maintain the particular flight condition. On what materiel deficiency report should this condition be recorded?

3. A new aircraft is received. You find that a large number of screws are missing and some loose, and several amplifier rubber mounts are not properly installed. Personnel or equipment is not a factor. Under what materiel deficiency report category should this condition be recorded?

4. What type of unsatisfactory materiel report should be used to report an equipment deficiency that would reduce the operational life of equipment?

2-4. Aircraft Forms

Your responsibilities to the aircraft records and aircraft documents vary with your assignments.

You will maintain equipment and train and, eventually, supervise other personnel. A high percentage of these tasks are recorded on aircraft or aircraft-related forms.

041. Cite standard practices and entries used to complete the AFTO 781 series forms.

There are certain standard practices that you must adhere to in your use of the AFTO 781 series forms. As a minimum, we discuss legibility, signatures, dates, and abbreviations. All other cautions or requirements are noted as they apply to the form under discussion.

Uniform Entries. A more-than-ordinary effort should be made to make the entries complete, correct, legible, and neat. These records are handled by various personnel who must file, extract information, and prepare other records and forms from them. It is therefore of the utmost importance that you make legible entries properly—or have them made so—to reduce the possibility of errors caused by someone's interpretation of your careless entries. To achieve correct and legible entries, it is recommended that you make entries with pencil to allow correction of minor errors. Although discouraged, it is not an error to make entries in ink.

The minimum signature used on most maintenance forms is the first name initial, complete last name, and rank or grade. This entry is always made in script by the actual person; it is printed if transcribed to other documents by another individual. Exceptions exist to this policy as there are with nearly all policies, but they are rare.

The dates used on these forms generally consist of five digits separated by slashes. That is, the day is recorded by using two numerals, the month two, and the year only one numeral. An example for the date 12 January 1983 is 12/01/3. An exception to this rule is the use of six numerals when recording the dates on some positions of the AFTO Form 350. These exceptions are primarily attributed to the fact that the information on this form is transferred to computer punch cards.

Abbreviations. Standard abbreviations that aid in a concise and readable form entry are recommended. The key to remember, though, when you are using any shortened work form is, "Will the reader understand?" If you cannot answer this question in the affirmative, you should spell it out. Several standard abbreviations are listed in the first section of TO 00–20–1, *Preventive Maintenance Program General Requirements and Procedures:* e.g., DN for "document number" or IAW for "in accordance with."

Exercises (041):

1. Why are accuracy, neatness, and legibility stressed in the handling of AFTO 781 series forms?

2. According to the 00–20 series technical orders, what constitutes a minimum signature for most aircraft forms?

3. If you were writing the date, October 15, 1984, on aircraft forms, how would you record it?

4. What standard rule should you adhered to in using abbreviations?

042. Explain selected symbols used on AFTO 781 series forms in terms of their purpose and meaning.

Symbols and Their Use. Certain symbols described in this section are established for use on maintenance documents to make important notations instantly apparent. They indicate the mechanical condition, fitness for flight or operation, servicing, inspection, and maintenance status of the system concerned. Of these, particular symbols are entered in red to make the important warning signals stand out more clearly. Thus, the red X represents the most serious possible condition: the circled red X, the next most serious condition: the red dash, the next most serious: and red diagonal, the least serious condition. You must memorize the relative importance of these symbols to insure proper entries on maintenance forms.

You enter these symbols on several of the AFTO 781 series forms, giving the most attention to the Status Today block of the AFTO Form 781H, *Aerospace Vehicle Flight Status and Maintenance Document*. Remember, these symbols reflect the seriousness of the discrepancy in the opinion of the individual making the entry. If a person of higher authority within the maintenance activity believes the symbol chosen does not properly reflect the condition, the superior may upgrade or downgrade the symbol to one considered more appropriate.

Once entered on any maintenance document, a symbol must never be erased, even if it has been entered in error. This restriction on erasing symbols is necessary to insure that the opinion of the individual who made the entry is thoroughly evaluated before a symbol is changed, and that even an erroneous symbol entry is properly cleared. In this way, no doubt is left about the integrity and validity of the symbols entered. If an erroneous symbol is entered in the Sym block of the AFTO Form 781A, *Maintenance Discrepancy and Work Document*, the individual making the entry must enter the following statement in the Corrective Action block: "Symbol entered in error, item reentered page entered in error, item reentered page __________ , item __________ ." The discrepancy is then entered in the next open Discrepancy block, with the correct symbol. As an example, if the erroneous symbol is a red X, an authorized individual must initial over the symbol and sign the Inspected By block.

Red X. As already indicated, the red X is the most serious symbol. It indicates that the aircraft is considered unsafe or unfit for flight and must not be flown until this unsatisfactory condition has been remedied. No one may authorize or direct that an aircraft be flown until the red X has been properly cleared. After work has been done to clear the discrepancy, there must then be an audit of all related entries involved. They must be checked for completeness and accuracy. Each red X symbol will always be a separate AFTO Form 781A entry. The following are some of the typical situations which call for the use of the red X symbol:

a. Immediately upon discovery of an unsatisfactory condition serious enough to warrant its use.

b. Upon receipt of an immediate action technical order.

c. When work or inspections are performed in or around the air intake areas of jet engines. The red X must be used to insure inspection of the engine intake ducts and areas forward of the intake ducts. This inspection must be accomplished prior to engine start to insure that there are no objects that could be ingested by the engine.

d. When maintenance is performed on aircraft flight control systems or components.

e. When maintenance or aircrew reported defects or unsatisfactory conditions of systems or components exist that could affect safety of flight—defects or conditions which cannot be physically located or cannot be operationally duplicated.

f. Upon removal of any component or assembly that affects safety of flight or safe operation of the equipment.

g. When the removal and replacement of any component or assembly is such that improper reinstallation would affect flight safety or create an operational hazard.

h. When a weapon or support system is out of commission for an engine change.

i. hen a scheduled inspection is in progress for a weapon or support system or equipment, excluding preflight (PR), thruflight (TH), basic postflight (BPO), and home station check (HSC) inspections on aircraft and daily inspections on missiles or other equipment. The decision to apply the red X for preflight, basic postflight, and daily inspections rests with the maintenance supervisor or higher local authority.

j. When an egress system has been partially or completely disassembled.

k. When maintenance is performed on the fuel system or any fuel system component while installed on the aircraft or auxiliary power unit (APU).

l. When an aircraft brake or nose gear steering system is inoperative. Aircraft with inoperative brakes must not be towed or taxied until the red X symbol has been cleared. However, this restriction may be waived by the maintenance supervisor or chief of maintenance under emergency conditions.

m. When a "jump wire" or other type of shorting device is installed in an electrical system while maintenance is being performed.

n. When the aircraft weight and balance status is unknown.

Circled red X. The circled red X is used to indicate that the aircraft has been grounded, pending compliance with an urgent action technical order. When an urgent action TCTO is received and is not immediately started, it is placed in the aircraft forms on a red diagonal. A time limit is attached to the compliance of this TCTO (usually from 1 to 10 days). When this time limit expires, or when work is started, a circled red X is entered on the aircraft forms. The circled red X is treated in the same manner as is the red X.

Red dash. The red dash symbol indicates that the condition of the equipment is unknown. This symbol denotes that an inspection is due and has not been completed; that a functional check flight has not been made; or that an accessory, though scheduled for replacement, has not been replaced. So you can see that the red dash may be an erroneous symbol, in that a red X condition could exist, since the equipment has not been examined to ascertain its true condition. The red dash symbol requires an exceptional release in block 9 of AFTO Form 781H, if the aircraft is to be flown.

Red diagonal. The red diagonal indicates that an unsatisfactory condition exists which may affect the flying safety or the flying efficiency of the aircraft, but it is not sufficiently urgent or dangerous to warrant grounding the aircraft. The diagonal is entered in the appropriate block, extending from the upper right-hand corner to the lower left-hand corner of the block.

Black last name initial. The black last-name initial indicates that the aircraft is in a satisfactory condition for use. The black initial may be placed over a red symbol to indicate that the condition has been corrected. Therefore, a red symbol is never entered over an initial—you must use the next open block to indicate the change in condition from satisfactory to unsatisfactory.

Exercises (042):

1. What do red symbols in aircraft maintenance forms represent?

2. Name the status symbols used on aircraft forms in descending order.

3. When is it permissible to erase a red symbol? Explain briefly.

4. If your wing received an immediate action technical order, what symbol would you select to enter in the forms?

5. If personnel under your supervision had started work on an urgent action TCTO, what symbol would you expect to see in the AFTO Form 781A and 781H to represent this condition?

6. Simply stated, what does a red dash represent?

7. A discrepancy that may affect the flying efficiency or flying safety of the aircraft, but which is not sufficiently urgent enough to ground the equipment, would be represented by what symbol?

8. If you saw a black last-name initial over a red symbol in the aircraft forms, what would it mean?

9. Give the purpose of using red symbols.

043. State entries required on AFTO Form 781A and give the reason for specific entries.

AFTO Form 781A. This form is designed so that each deficiency and discrepancy reported by the pilot or an aircrew member, or discovered by the maintenance personnel, can be identified and documented for historical and filing purposes. The form, shown in figure 2-5, is identical on the front and back sides; it contains spaces for four different discrepancies on each side. Each side is treated as a page when the completed forms are removed from the aircraft binder, and forwarded to the records unit for filing.

The heading line at the top of the form is filled in by the crew chief. The Date From and To blocks denote when that particular set of forms (those pages numbered consecutively) were initiated and closed out. The Date From block indicates that the last set of forms were removed on that date, while the To date indicates the date on which those forms were removed from the binder and forwarded to the documentation section. It is important for you to remember that the date placed in the Date From block of the new set of forms is the same as the TO date that appeared on the previous set. This rule must be followed to provide a positive means of determining whether any forms are missing from the aircraft file.

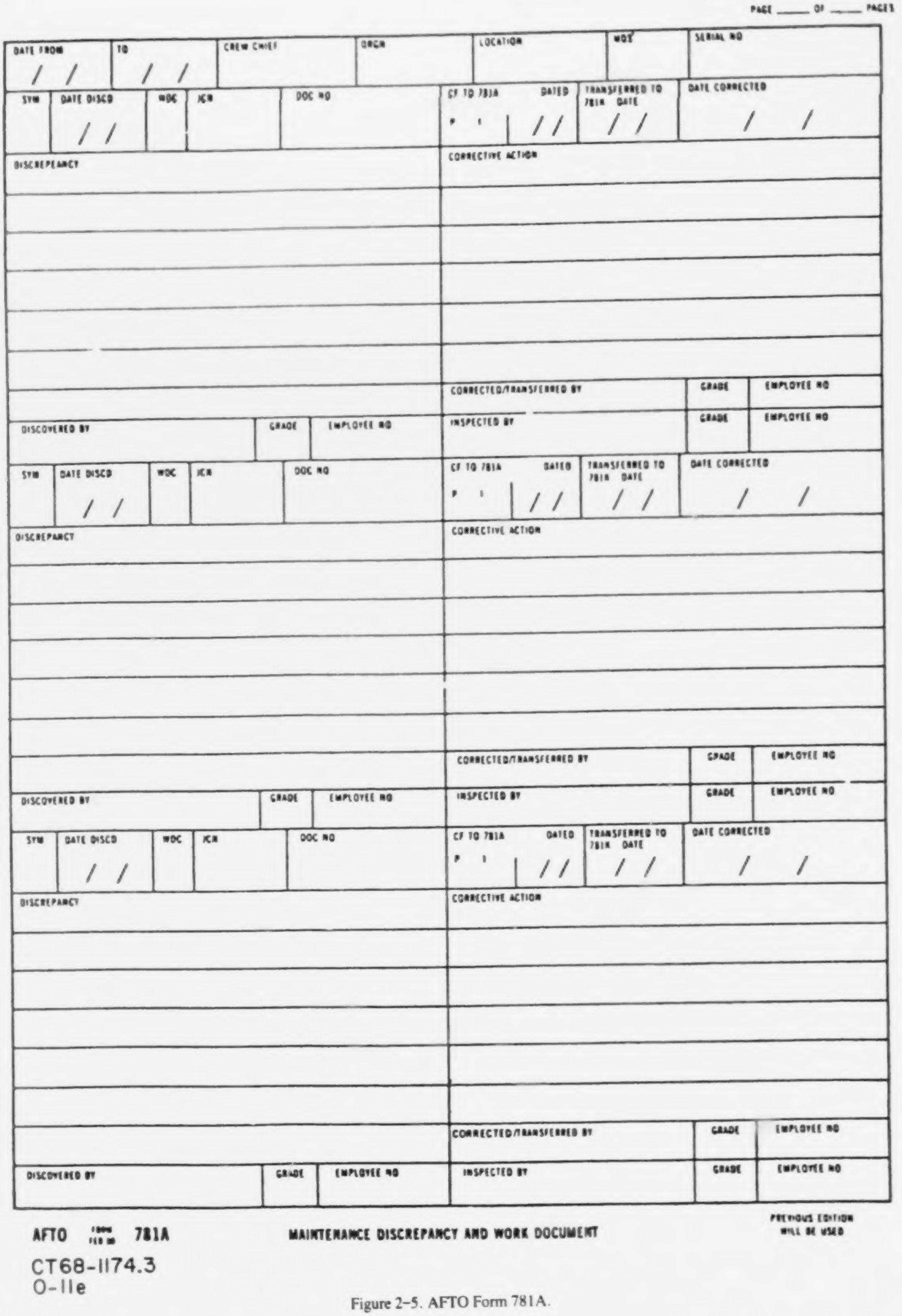
The heading on succeedings pages need not be as complete as the first sheet. For instance, the second page and all other even-numbered pages of that set would need only a page number. The third page and all other uneven-numbered pages would require a minimum of page number, From and To dates, MDS, and serial number. This would mean that if four sheets were removed from the aircraft binder at the same time, they would be securely fastened together and would carry the same From and To dates, with a page-numbering notation such as Page 1 of 9 Pages, Page 2 of 8 Pages, etc., through Page 8 of 8 Pages.

Discrepancy block. The Discrepancy block is used to note any defect that exists on the aircraft, whether it is due to accident, deliberate removal, fair wear and tear, or something else. Only one defect is entered in any one block. Pilots making entries indicate the flight number as the first portion of the defect entry. If the aircraft is radioactive, if the oil has been diluted, or if the engines have been placed in storage, the Discrepancy block is used to denote these conditions.

The blocks above the Discrepancy block serve to clarify and control information it contains. We have already discussed symbols and dating, but the remaining three will be covered here. The WDC block represents the when-discovered code and is entered by the pilot if anything has been discovered in flight.

One of the methods used in identifying, controlling, and analyzing maintenance actions is the job control number. This seven-digit code is issued by plans and scheduling, either directly or in blocks, to maintenance activities for their use. Each code is unique to the job to which it is assigned and stays with that job until its completion.

The Tag Number block is another control device used in keeping track of reparable property. After repairing a piece of equipment, a technician records this work accomplishment on the AFTO Form 781 series forms. This work is also recorded, for statistical purposes, on another form, the AFTO Form 349, Maintenance Data Collection Record. If that repair action involves reparable property,



PAGE ____ OF ____ PAGES

DATE FROM / /	TO / /	CREW CHIEF	ORGN	LOCATION	MDS	SERIAL NO

SYM	DATE DISCD / /	WDC	JCN	DOC NO	CF TO 781A P I	DATED / /	TRANSFERRED TO 781K DATE / /	DATE CORRECTED / /

DISCREPANCY

CORRECTIVE ACTION

CORRECTED/TRANSFERRED BY | GRADE | EMPLOYEE NO

DISCOVERED BY | GRADE | EMPLOYEE NO

INSPECTED BY | GRADE | EMPLOYEE NO

SYM	DATE DISCD / /	WDC	JCN	DOC NO	CF TO 781A P I	DATED / /	TRANSFERRED TO 781K DATE / /	DATE CORRECTED / /

DISCREPANCY

CORRECTIVE ACTION

CORRECTED/TRANSFERRED BY | GRADE | EMPLOYEE NO

DISCOVERED BY | GRADE | EMPLOYEE NO

INSPECTED BY | GRADE | EMPLOYEE NO

SYM	DATE DISCD / /	WDC	JCN	DOC NO	CF TO 781A P I	DATED / /	TRANSFERRED TO 781K DATE / /	DATE CORRECTED / /

DISCREPANCY

CORRECTIVE ACTION

CORRECTED/TRANSFERRED BY | GRADE | EMPLOYEE NO

DISCOVERED BY | GRADE | EMPLOYEE NO

INSPECTED BY | GRADE | EMPLOYEE NO

AFTO FORM FEB 80 **781A** MAINTENANCE DISCREPANCY AND WORK DOCUMENT PREVIOUS EDITION WILL BE USED

CT68-1174.3
O-11e

Figure 2-5. AFTO Form 781A.

the AFTO m 350, Reparable Item Processing Tag, must also be initialed. This Form is attached to the part by the maintenance technician. The tag number that appears on the AFTO Form 781A is taken from this form.

The Discrepancy block, as we have mentioned earlier, is used to record the malfunction or deficiency in the words of the individual discovering the condtion. Only one discrepancy is allowed per block, although as many blocks as needed may be used if the explanation is lengthy. The person, who generates the writeup, signs in the Discovered By block, with at least the minimum signature.

Before we go on to the Corrective Action block, we should briefly explain the entry in the DN or Document Number block. This entry, similar to the job control number, identifies the organization and date of the supply transaction.

Corrective Action block. The use of this block is self-explanatory. When a defect entered in the Discrepancy block opposite this block has been corrected, the action taken to accomplish the task is entered as briefly as possible in the Corrective Action block. There are few restrictions or requirements for these entries, but some do exist. For instance, when the corrective action requires technical references, torquing, operational checks, or other verification, such should be entered in this block. If a discrepancy cannot be duplicated in that maintenance personnel are unable to make the equipment malfunction as described in the Discrepancy block, the facts are stated in the Corrective Action block. Enter this only after the best qualified maintenance man has investigated the malfunction to assure that all possible avenues have been pursued. One other important requirement is the unscheduled replacement of time change items. If this equipment is changed before the normal life cycle ends, this corrective action must be underlined in red for the benefit of the documentation personnel, who must post this information in the appropriate records.

When the corrective work has been done, this action must be attested to by the responsible technician. If the work is routine and does not require inspection, then the mechanic who accomplished the task must sign the Corrected By block and enter grade and employee number. This same mechanic will then place his or her last name initial over the red symbol in the Discrepancy block. If the work requires final inspection because of the seriousness of the condition, then this final inspector's signature is placed in the Inspected By block, and it is his or her last name initial that is placed over the symbol.

When a new AFTO Form 781A is initiated, any uncorrected discrepancies other than red-X items may be transferred to the AFTO Form 781K, Aerospace Vehicle Inspection, Engine Data, Calendar Item Inspection and Delayed Discrepancy Document. The name of the individual, who makes the initial entry in the AFTO Form 781,A need not be retained with the discrepancy when the entry is transferred to the AFTO Form 781K or carried forward to a new AFTO Form 781A. When a discrepancy is carried forward to a new AFTO Form 781A, the crew chief or an alternate must enter the page number, item number, the date of the new form, and signature and grade in the Transferred By block. If the discrepancy is to be transferred to the AFTO Form 781K, the alternate must enter the date of the transfer action, signature, and grade in the Transferred By block. An initial should not be placed over the symbol for discrepancies that are carried forward or transferred to another form, since this only represents transcribing action and does not correct the reported condition. When a discrepancy is carried forward to a new AFTO Form 781A or is transferred to the AFTO Form 781K, the job control number, and if applicable, the supply document number and AFTO Form 350 tag number must be carried forward with the discrepancy.

Exercises (043):

1. Who is responsible for filling in the heading line at the top of the AFTO Form 781A?

2. What entry is recorded in the Discrepancy block on the AFTO Form 781A?

3. You discover two discrepancies on an aircraft. How many Discrepancy blocks in the AFTO Form 781A should you use to record these discrepancies?

4. When must you underline the corrective action in red?

5. When may "malfunction cannot be duplicated" be entered in the corrective action block?

6. Why is each aircraft discrepancy identified on the AFTO Form 781A?

CHAPTER 3

AF Occupational Safety and Health Program

THE AIR FORCE conducts a comprehensive and aggressive program to protect all Air Force personnel from work-related deaths, injuries and occupational illnesses. While you are in the Air Force, you will be continually alerted to the dangers involved while performing as an aircraft electrical systems specialist or technician. Your safety instruction will include lectures given by people from the safety office, your supervisor, and your coworkers. Posted safety signs, bulletins, and safety notes interspersed throughout the manuals and TOs are also used to emphasize safety.

Instructors and literature on safety alone cannot and will not prevent you from having an accident. Only thinking can prevent accidents, and this thinking must come from you. What thinking? You must THINK and PRACTICE safety at all times. You must think about safety to the point that it becomes an automatic reaction. When you reach this objective, you become safety conscious and take positive action toward safety. When people visit a steel foundry and are permitted to view the hot molten cauldrons of steel from a walkway above, most of them stand well back. This is being "safety conscious." Since the dangers are apparent, viewers take positive safety steps by keeping away from the edge of the walkway. Flight-line safety sometimes is not so apparent; so we must use various means to identify inherent dangers.

In this chapter and throughout the CDC, we discuss safety and you. We point out some of the high-accident-rate areas where you will be required to work. The areas that we discuss are areas where accidents have happened to others. When it comes to accidents, it is less painful to learn from the mistakes of others. Don't become an accident statistic—THINK SAFETY.

3-1. Flight-Line Safety

Safety is the responsibility of every individual in the Air Force. This includes personal safety and the safety of others. As a trainer, you are responsible for instructing personnel in the safety practices applicable to the operations performed. Likewise, it is your responsibility as a repairman of electrical and electronic equipment to understand and observe the safety standards and regulations established for your unit.

The installation, maintenance, and operation of electrical and electronic equipment have several elements of danger. Carelessness on your part can result in serious injury or death as a result of electrical shock, falls, burns, flying objects, etc. The chief causes of accidents are unsafe conditions and unsafe acts. As an aircraft electrical systems specialist, it is your responsibility to identify and eliminate unsafe conditions which cause accidents. In practically every instance, unsafe conditions are identifiable and can be eliminated by exercising foresight and common sense. Unsafe acts can be reduced if each repairman is repeatedly informed concerning safety matters.

044. Cite the most frequent causes of Air Force accidents and tell how these accidents can be prevented.

Safety for the Aircraft Electrical System Specialist. There are three primary factors that produce accidents. They are as follows:

a. Deficiencies in equipment design.
b. Faulty operating procedures.
c. Human error.

The most frequent cause of accidents is human error. This can be substantially reduced by safety training and by enforcement of safety rules. Your safety and the safety of others depend largely upon what you do. It is your duty to observe every precaution during aircraft storage, handling, maintenance, and operation. Also, it is your responsibility to know and use safety practices, standards, and regulations. These have been established for the prevention of injury and damage. Many of us believe that accidents are the result of an uncontrollable condition. According to all the information the Air Force can collect, accidents are not the result of unchangeable circumstances. Fate has nothing to do with it. About 98 percent of the accidents that occur can be prevented. The cause must be identified and isolated. You must take all safety precautions possible to prevent or eliminate unsafe acts and conditions.

Safety involves not only following safety procedures during maintenance activities but also includes precautions during emergencies that happen less often. Knowledge of what to do in these situations helps you keep a "clear head." Know the procedures to follow in unusual situations. Familiarity with aircraft, equipment, and components makes any necessary action easier. Time may be an all-important factor.

Exercises (044):

1. What is the most frequent cause of accidents?

2. How can most accidents be prevented?

3. What percent of Air Force accidents could be prevented?

045. Cite the danger areas and hazardous conditions present around an operating jet aircraft engine.

Jet Engine Dangers. Operating jet engines are the source of another of the hazards that you must be aware of when working on the flight line. The major danger areas are (1) engine intake, (2) engine exhaust, (3) engine turbine plane, and (4) cartridge starter plane. When engines are operating at high power settings, the area behind the lip of the engine intake is very dangerous up to distances of 4 feet aft of the lip. The noise level is also a significant danger in that it ultimately reduces the acuteness of the sense of hearing.

There have been instances when the turbine wheel has disintegrated in operation. If this happens while you are standing in the plane of rotation, you may be cut to pieces by flying parts traveling at speeds far above the muzzle velocity of a rifle. For this reason, always stand fore or aft of the plane of rotation when the engine is being operated on the ground. To make this danger area easy to locate, a painted RED strip may mark the danger point on the aircraft. Therefore, before working on any turbine engine aircraft, you should check the applicable technical order to determine exactly where the plane of rotation of the engine turbine is located. The cartridge starter is essentially a small turbine; it is rotated by the blast from a high-powered cartridge. The danger area (in respect to the engine or starter) is normally 200 feet in the plane of rotation on either side of the aircraft.

Engine intake and exhaust. Two sources of very serious injury and very often fatalities are the engine intake and exhaust blast areas. These two areas really require your attention, because these are not the types of danger which MIGHT cause you pain. They are the types that WILL cause you pain, as explained in the following paragraphs.

The high velocity and high temperature of the jet engine's exhaust blast make it particularly hazardous to personnel; it is to be carefully avoided. A safe distance is considered to be about 200 feet to the rear, but the exhaust blast area is not the same for all aircraft, so check the proper technical order on the aircraft with which you are working.

The suction effect of an operating jet engine intake is sufficient to cause fatal injury to personnel and extensive damage to equipment (see fig. 3-1). A safe distance from these intake ducts is normally 25 feet to the front and sides of the duct. On one of the more advanced aircraft, the technical order cautions that danger also exists in an area which extends to 4 feet aft of the intake lip.

To aid in preventing accidents involving engine intake ducts, never wear loose clothing or carry objects that might be drawn into the intake.

Engine noise. Before we leave the jet engine, there is one more subject worthy of mention: NOISE. You have heard it, I'm sure. If you haven't, then you might make a trip to the flight surgeon's office to learn the reason. Take it from those who now wear hearing aids, the best place for your earplugs is in your ears; i.e., when you are on the active flight line or around any noisy equipment. Make sure your earplugs fit—and use them!

One word of caution about earplugs and other types of ear protection. When you wear them, watch where you walk. Why should you? Because if the engine is running, and you can't hear it, you may enter danger areas without realizing it.

Exercises (045):

1. List the major danger areas around an operating jet engine.

2. Why is the plane of rotation of the engine turbine wheel considered dangerous?

3. List the ways in which you can determine where the plane of rotation of the engine turbine is located.

4. What conditions make the engine exhaust blast particularly dangerous?

5. How would you determine the safe distance behind an operating jet engine?

6. What condition causes the danger area around an operating jet engine intake?

7. What is normally considered a safe distance from an operating jet engine intake?

8. What protective equipment should you wear around a jet engine?

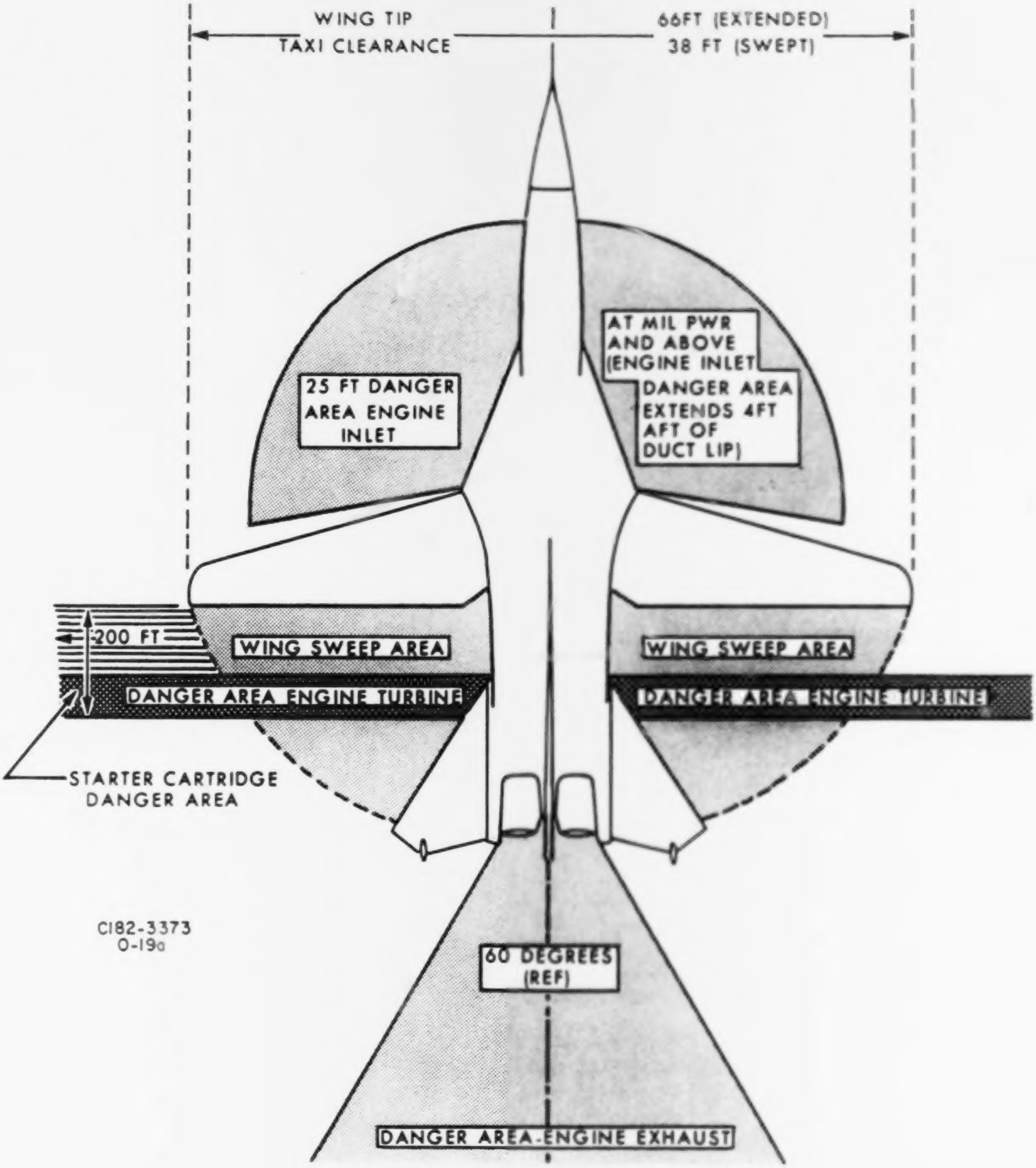

WING TIP
TAXI CLEARANCE
66FT (EXTENDED)
38 FT (SWEPT)
25 FT DANGER AREA ENGINE INLET
AT MIL PWR AND ABOVE (ENGINE INLET DANGER AREA EXTENDS 4FT AFT OF DUCT LIP)
200 FT
WING SWEEP AREA
WING SWEEP AREA
DANGER AREA ENGINE TURBINE
DANGER AREA ENGINE TURBINE
STARTER CARTRIDGE DANGER AREA
C182-3373
0-19a
60 DEGREES (REF)
DANGER AREA-ENGINE EXHAUST

Figure 3-1. Danger areas of an F-111.

046. Cite the warnings which indicate that an aircraft is armed.

Armed Aircraft. Many fatal accidents and extensive aircraft damage have resulted from maintenance personnel working on aircraft which were armed. By "armed" we mean that the aircraft has explosive weapons such as bombs, missiles, or ammunition installed. Normally, the maintenance performed is very limited when an aircraft is armed. Let us look at some of the ways in which you can determine if an aircraft is armed. Armed aircraft are easily identified by such items as safety pins with red streamers attached on the arms device, also by warning signs placed near the cockpit entrance. In addition, the AFTO Form 781H, Aerospace Vehicle Flight Status and Maintenance Document, will have an entry in block II, gun or rocket status. The entry "Hot" or "Cold" is entered in red in the status block, and the quantity of rounds or rockets on board is entered in the quantity block. On certain types of aircraft, the following entry is found across the status blocks: "See AFTO Form 781C." The AFTO Form 781C, Avionics Configuration and Load Status Document, is used when warranted or when directed by the concerned command.

It is beyond the scope and requirements of this CDC to publish all the specific information regarding the performance of maintenance on armed aircraft. You must consult the applicable aircraft and system technical order and follow procedures exactly.

Exercises (046):

1. When you approach an aircraft to perform maintenance, what is normally the first indication you would have that the aircraft is armed?

2. Where would you look in the aerospace vehicle flight status and maintenance document to determine if the aircraft is armed?

3. When is the AFTO Form 781C used?

047. List the sources and effects of radio-frequency radiation and state precautionary measures.

Radio-Frequency Radiation. We now mention dangers that are beyond your ability to see or hear. These are called radio-frequency (RF) transmissions. *Electromagnetic radiation* is another name applied to this hazard. RF radiation is given off by high-frequency radio transmitters, radar, and electronic countermeasure devices. The hazardous high-frequency radar transmitter is often hidden behind the nose cone of an aircraft. Energy radiated by radar transmitter antennas can cause flash bulbs to ignite and steel wool to burn. It can cause burns beneath the skin and cataracts over the eyes. Since the presence of this energy may not be apparent, injuries may occur before you feel any pain. When electromagnetic energy is absorbed in the tissues of the body, heat is produced. If the internal body heat cannot be dissipated as fast as it is produced, the internal temperature of the body will rise. Internal organs can be easily damaged by excessive heat from exposure to radiation.

To avoid this danger, don't stand in the beam of a nearby radar antenna! You can't tell if your internal organs are being heated, and serious damage can be done before you know it. Wherever possible in a maintenance situation, all personnel should avoid the area of radiating power from radar antennas.

If it is not possible to radiate the power into space or couple it into a dummy load, then a radiation absorption screen should be used. Radiation hazards depend upon a great many variables, such as time of exposure, strength of emission, weather, and the number of units operating in the area. Use common sense, good judgment, and experience to evaluate these variables.

Exercises (047):

1. List three sources of RF radiation.

2. What are the effects of RF radiation on the human body and vital organs?

3. What basic precaution can you take to avoid exposure to RF radiation?

4. What protective device may be used for partial protection against RF radiation?

048. List safe procedures to follow when working around reciprocating engines.

Reciprocating and Turboprop Engines. To some, propeller-driven (prop) aircraft may seem outdated. Nevertheless, we may have to work around them from time to time. There is one area you must stay clear of, and that is the propeller. Some people develop the habit of walking between the prop blades when the aircraft is located in the docks. This seems harmless, but suppose one day, through force of habit, you do it on the flight line. What happens? You end up with a permanent part in your hair that reaches to your belt buckle. What are we saying? Props have no regards to rank, habits, or anything else. Always treat them as though they are turning, or about to turn.

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0-10j

Figure 3-2. Switchitis.

Helicopters. This type of aircraft can be powered by either a reciprocating or jet engine. The helicopter is sometimes referred to as a rotary wing aircraft. The lift required for flight is provided by rotor blades which are powered by the engine. You must be aware of the danger areas formed by these rotors. There are certain places within the rotor path that allow you to approach the fuselage of the aircraft with the rotors turning. You need to know these areas before you attempt to enter the rotor path. Each type helicopter is different, so refer to the applicable technical order for the type helicopter you might be assigned to work on.

Exercises (048):

1. What area should be avoided when working around a reciprocating engine?

2. Where can you find the safe way of approaching a helicopter?

049. Cite the hazards of the swing wing feature on advanced aircraft and the precautions to observe.

Variable Wing Dangers. One type of aircraft in the Air Force inventory contains a feature that presents another very hazardous condition. The wings, equipped with leading edge slats and trailing-edge flaps, may be varied in sweep, area, camber, and aspect ratio by selecting any sweep angle between 16° and 72.5° (see fig. 3-1).

This means that the wings can be moved or swept back from a nearly straight-wing configuration to a position where the trailing edges actually fit into slots that are built into the length of the fuselage. At full sweep, part of the wing trailing edge is parallel to and only inches away from the leading edge of the horizontal stabilizer. The wings are hydraulically actuated and can be moved through the full range of travel when the aircraft is on the ground.

The main hazard present is the danger of maintenance personnel being caught between the trailing edge of the wing and the leading edge of the horizontal stabilizer or the side of the fuselage. A hazard is always present on any power-actuated surface such as speed brakes, spoilers, flight control surfaces, weapons bay doors, and arresting tailhooks; but the fact that the wing could sever a human body makes this area particularly dangerous.

Precautions you should observe are these:

- Stay clear of the wing-sweep radius when the wing positions are being varied.
- Insure that should you be required to perform maintenance anywhere in the wing-sweep radius area, a responsible person is aware of where you are working.

Exercises (049):

1. Cite the hazard present on aircraft having the swing-wing feature.

2. List the special precautions you should observe when working on swing-wing aircraft.

050. State hazardous conditions present in the cockpit.

An area that people with the disease "switchitis" need to avoid is the cockpit. You won't find this word in the dictionary. It is a term that describes a person who just has to touch, turn, or snap every switch visible. The results can be fatal (see fig. 3-2).

Cockpit Area. The modern aircraft cockpit, like a loaded gun, is deadly in the hands of the inexperienced. Located in the cockpit are the controls for explosives, wing tanks, canopies, ejection seats, flaps, and the landing gear. All of these controls can be killers. Learn the cockpit details of all the aircraft on which you are required to work. Be able to recognize nonstandard equipment. Know exactly what each switch and lever does. Use caution so that you do not accidentally lean or brush against any handles, switches, or levers. Never pull a handle or flip a switch if you do not know what the results will be. You, or a coworker, may be in for an unexpected ride—your last! Accidental firing of ejection seats and canopies can result in serious personal injury and in damage to the aircraft. As a safety precaution, seat and canopy safety pins with streamers are installed immediately after flight, and they remain installed while the aircraft is on the ground. Nevertheless, exercise extreme caution to avoid accidental firing of the canopy or seat. You are not authorized in the cockpit until you have attended the cockpit familiarization training for each type aircraft you are required to maintain. If you don't know what you are doing, don't do it. THINK AND LIVE!

Be aware of other people working on the aircraft. Especially if electrical or pneudraulic power is applied. If you accidentally hit the wrong switch at the right time, someone could be seriously hurt. Many times you will be required to work on the aircraft with power applied. On some of these occasions, you may not want power on your system. If this be the case, pull the circuit breaker, but don't stop there; tag it so no one will reset it. By doing this you could prevent a shocking situation from happening to you. If you ever feel "switchitis" coming on, get away from the aircraft immediately. The cockpit area may present a hazard in other ways also. An oxygen leak could create an oxygen-enriched environment. One flip of a switch, or a spark from a tool you drop, may cause the entire area to be engulfed in flames.

Exercises (050):

1. What is the greatest cockpit environmental hazard on most aircraft?

2. When are the canopy and seat safety pins installed?

3. What should you do if you are required to work on an aircraft with electrical power applied and you don't want power on your system?

4. When are you authorized access to the cockpit area of an aircraft with an ejection seat?

051. List the different types of nuclear radiation and cite the protective measures that should be observed.

Nuclear Radiation. The final form of destruction resulting from atomic explosion or exposure to contaminated equipment is nuclear radiation. Although nuclear radiation is the least likely hazard met on the flight line, still it may exist in the event of an accident while handling a nuclear weapon. It may also exist if an aircraft carrying a nuclear weapon should crash. One of our planes may fly through a contaminated zone and, upon its return, need repair. Should this happen, it would be necessary that we know the degree of contamination so that it can be determined how much exposure to the contaminated aircraft the maintenance personnel could withstand.

Radiation is invisible. We have only one way to show its presence and that is by placing radiation placards in the area. Study the symbol in figure 3-3. Learn its shape and colors—magenta (reddish purple) symbol on a yellow background. It may save your life. Nuclear radiation consists of alpha, beta and gamma rays.

Alpha radiation. Alpha radiation can be stopped by almost any barrier including an inch or two of air, and it becomes a hazard only if the material is taken into the body by breathing, eating or drinking contaminated food, or through broken skin surfaces.

Beta radiation. Beta radiation has a range of a few feet in air and has very little penetrating power; however, it may inflict severe burns on the unprotected skin as well as internal damage if ingested into the body. It can be stopped by ordinary clothing; however, you should wear protective clothing when working in a contaminated area. Beta rays like alpha rays can damage tissues when taken internally. Protective clothing and respirators are the only protection needed for either alpha or beta rays.

Gamma radiation. Gamma radiation can never be completely absorbed by any barrier. For this reason, it is the most deadly hazard to consider during any decontamination procedure. The intensity of the radiation is monitored by trained personnel. This intensity is expressed as a quantity of radiation per unit of time. The quantity unit of measure is the roentgen and the time unit is the hour; thus, intensity is expressed roentgens per hour (R/HR).

When working on or near contaminated equipment, you will be under the supervision of medical personnel. Wear a film badge or dosimeter so that the amount of radiation (dosage) you receive can be measured. This is put into your medical records. You will not be allowed to collect too large a dosage. After working on a contaminated aircraft, immediately take a shower. Then check to see that you have removed all the radiation particles. If you are free of radiation, dress in clean, contamination-free clothing. Waste materials from cleaning contaminated equipment is disposed of by burial. This is done away from any maintenance activity.

Depending on the unit you are in, you may be trained in nuclear safety. The 122 series of regulations cover this area in depth. The two regulations you will probably use the most in this area are AFR 122–1, *The Air Force Nuclear Safety Program*, and AFR 122–4, The Two-Man Concept.

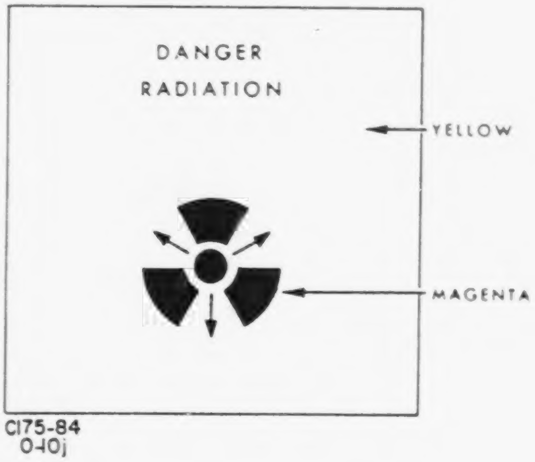


Figure 3-3. Radiation placard.

Exercises (051):

1. List the types of destructive rays of nuclear radiation.

2. Which type of radiation can be stopped by an inch of air?

3. Which type of radiation can be stopped by ordinary clothing?

4. Which type of ray is given out by nuclear radiation and is considered the most deadly?

5. How is the intensity of radiation expressed?

6. What will happen when alpha and beta radiation are taken internally?

7. What type of device is required to be worn when working near contaminated equipment?

8. List the conditions where nuclear radiation could be encountered on the flight line.

9. Describe the appearance of a radiation placard.

3-2. Foreign Object Damage (FOD)

What is foreign object damage (FOD)? It is usually defined as the damage to gas turbine engines caused by objects being drawn into the engine compressor. How does FOD affect you? It could affect you both financially and personally. For instance, when aircraft equipment is damaged or destroyed, the Air Force must repair or repurchase it. Who supplies this money to the Air Force? You, as one of many taxpayers do; or you alone, if it is due to your carelessness. Now, let's assume that a screwdriver enters the engine compressor section, the turbin wheel blades disintegrate, and a friend of yours is seriously injured or killed from the fragmented turbine wheel. How would you feel if you had to go through life knowing that your carelessly left screwdriver caused your friend's injury or death? You could also be required to pay for the damaged aircraft if carelessness could be proven.

052. Correlate foreign objects and FOD classifications.

Classes of FOD. Generally, foreign objects that are hazardous to aircraft gas turbine engines are in one of three basic classes: metal, stone, or miscellaneous. Let's briefly discuss each.

Metal. This class consists of aircraft and engine fasteners (nuts, bolts, washers, safety wire, etc.) and extra flight-line metal (nails, personnel badges, pens, pencils, etc.).

Stone. This class consists of natural stone (pebbles, gravel, sand, etc., in their natural state) and unnatural stone (concrete, cinders, etc.).

Miscellaneous. This class consists of wood, organic matter (animal or vegetable matter), wearing apparel, hard plastics, ice (hailstones, frozen or hard-packed snow), and large pools of water.

The foregoing classes and types of foreign objects cause the most damage to gas turbine engine compressors. The tendency has been, in most preventive action, to consider all FOD as a single problem. Some problems, however, cannot be corrected when they are considered as a whole, but can be solved only when they are broken down into categories. Therefore, in taking preventive action it is better to assign FOD damage to the basic classification.

Exercises (052):

1. Match the FOD classifications in column B to the appropriate item(s) in column A that are related to gas turbine engine compressor damage.

Column A

____ (1) Mechanic's hat.
____ (2) Chips of concrete.
____ (3) Ballpoint pen.
____ (4) Mechanic's billfold.
____ (5) Finger ring.
____ (6) Cigarette lighter.
____ (7) Screwdriver.
____ (8) Leather gloves.
____ (9) Wristwatch.
____ (10) Rock.
____ (11) Frozen snow.
____ (12) U.S. coins.
____ (13) Safety wire.
____ (14) FOD tool checklist.
____ (15) Hard-packed snow.
____ (16) Padlock.
____ (17) House key.
____ (18) Mechanical pencil.
____ (19) Line badge.
____ (20) Paper clip.
____ (21) Glass bottle.

Column B

a. Metal.
b. Stone.
c. Miscellaneous.

053. State methods used to prevent FOD and benefits of a daily cleanup inspection.

Preventing FOD. The initial step in the development of an effective FOD prevention program is to identify possible sources of potentially dangerous foreign objects. Once these sources have been found, logical steps toward their elimination can be developed.

Metal foreign objects. Often, maintenance personnel fail to account for and dispose of nuts, bolts, washers, safety wire clippings, etc., during the removal, repair, and installation of components and parts. Special FOD containers should be provided for safety wire clippings, unusable nuts and bolts, etc. These special containers are doubly useful, because they also serve as reminders of the necessity for continual FOD preventive practices. Don't use your toolbox as a FOD container just because it is handy. Metal aircraft engine bits and pieces found in the vicinity of aircraft must not be ignored; they must be disposed of properly to avoid accidents.

Other good sources for metal foreign object damage are personnel identification badges and metal fasteners that could be drawn from clothing or that have been dropped in the vicinity of the inlet section. People working around aircraft or engines must insure that they use positive and reliable fasteners to secure their badges. Usually, a large safety pin is an effective fastener. Personal effects, such as pens, pencils, coins, etc., must be accounted for because they could cause much engine compressor damage.

At times, maintenance personnel fail to take inventory of handtools used in an aircraft or engine repair job upon its completion. As a result, engines are destroyed because a wrench, pair of pliers, or some other tool has found its way into an operating engine. To eliminate this sort of hazard, a checklist should be provided to all maintenance personnel.

Against this list, they must check their tools prior to and after each period of a maintenance task. We will go into this in more detail at the end of Chapter 4 when we discuss the composite toolkit program.

Stone foreign objects. Stones are probably the most difficult of all foreign object damage classes to combat; therefore, the cooperation of all personnel is necessary to prevent such damage. The immediate area that borders the edge of the runways and flight lines is probably the greatest source of stone foreign objects. Exhaust blast, ground vehicles, and sweeping tend to loosen debris so that it is easily tracked, blown by exhaust or wing, or washed onto the runway and parking areas. These items become potential hazards to aircraft gas turbine operation. Parking ramps, taxiways, and runways often will shown signs of cracking and chipping due to normal wear, weather, and other elements of nature. This situation, in turn, could create a FOD hazard. If by chance you observe such an area, you should notify Quality Control. Personnel from this branch will inspect the areas, and take the action necessary to correct the FOD hazard.

One of the means used to combat stone foreign objects is a mechanical or rotating sweeper. Another means is to spend a few minutes each day in an organized general inspection and physically pick up foreign objects in operational areas. Two immediate benefits are that (1) maintenance personnel become more conscious of the importance of FOD prevention and (2) the FOD rate is reduced.

Miscellaneous foreign objects. Local construction vehicles in operational areas are a prime source of wood foreign objects. Therefore, continuous cleanup procedures are necessary when there is construction in or near aircraft flight-line areas.

Organic (animal or vegetable) matter does not usually cause foreign-object damage to gas turbine engines. Large birds can be an exception. Concentrations of birds in the vicinity of runways represent a definite hazard. Normally, flight personnel are briefed on the probability of their presence.

Exercises (053):

1. List six methods used in the prevention of foreign object damage.

2. Cite two benefits derived from an organized daily cleanup inspection.

3-3. Ground Safety

The principal objective of ground safety is to eliminate or at least minimize accidents. This may be done by taking the following factors into consideration:

a. Accident causes.
b. Effects of accidents.
c. Controlling accidents.

As an aircraft electrician, you may be a potential accident victim. You need to respect electricity and know what could happen if you are not careful with it.

054. State hazards present when working with electricity and list the primary responsibilities of a safety observer.

Hazards and Precautions. The wide use of electrical and electronic equipment will expose you to many hazards. Poor judgment in the use and maintenance of this equipment is the major cause of injuries and damage. Training in equipment use and repair, and instructions on safety requirements will help reduce accidents. There is still the possibility of human error. Often we are so familiar with our jobs, that we become negligent. Negligence results in preventable accidents. The safety standards discussed in the following paragraphs are intended to offset this human error.

Shop electrical facilities. You are constantly exposed to the dangers of electrical shock, burns, and injuries received in fires that are caused by the improper use of electrical facilities and equipment. Short circuits, overloading, accidental grounding, poor electrical connections, and misuse of equipment are all responsible for many of the major accidents involving electricity. Inspect all electrical circuits and equipment for proper repair and operation. To prevent equipment damage or personal injury, always repair faulty equipment or wiring before operating.

Authorized electricians. Only qualified and authorized civil engineering (CE) electricians are authorized to install and maintain electrical generation and distribution circuits within the shop facilities. Makeshift wiring of any kind is prohibited. If you need more outlets, submit your request to CE on the proper forms.

Overloading circuits. Overloading a circuit at any time is extremely dangerous. All Air Force systems are required to be equipped with fuses, circuit breakers, or other accepted means to prevent accidents or hazardous overloading. DO NOT bypass protection devices. Again, if you need additional outlets, notify CE.

Cords and receptacles. Avoid excessive bending, stretching, and kinking of electrical supply (extension) cords. Replace or repair damaged electric wires, cords, and plugs. Equipment not used for long periods of time must be disconnected from the power source and stored where it won't be damaged. Be sure to re-inspect it before it is used again.

Low voltage. Treat low-voltage circuits with the same respect that you would high-voltage circuits. Severe shock resulting in death can be caused by contact with circuits carrying low voltage. Particular care must be taken to avoid contact with low-voltage circuits when working on ladders or other high places.

Equipment adjustments. Do not attempt to adjust any electrical or electronic equipment when there is a chance of receiving a shock from high-voltage components. In such cases, where equipment must be adjusted in the presence of high-voltage potentials, it must be done only when such work is authorized by applicable directives.

High voltage. High voltage is described as any circuit in which the potential from the source to ground or between conductors is 600 volts or more. Remember that any voltage capable of producing a current of 50 milliamps is very dangerous, and can even be lethal for some people if unusual conditions exist. These conditions include excessive humidity, wet areas, lack of protective matting, and exposed contacts.

High-voltage equipment carries with it certain hazards to which all operators and repairmen are exposed. One of the treacherous features of electricity is that its presence cannot be seen, heard, tasted, or smelled. Treat electrical and electronic devices with respect and caution. Do not make adjustments to high-voltage potentials where you might touch a ground connection or exposed circuit components. When working on energized (hot) equipment, be extra careful if your clothing is wet from perspiration, or if other moisture is present.

Unplugging components. The various components of electronic equipment carrying high voltages must not be unplugged with the power on. Regardless of voltages involved, if manpower is available, a safety observer must be present whenever work is being done on electrical equipment. Some components carry a residual voltage after power is removed, so be sure they are properly grounded before you work on them.

Safety observers. In those special cases where repair to high-voltage equipment is authorized, a safety observer must be present. The safety observer's primary responsibilities are to:

a. Enforce safety procedures.

b. Be able to give emergency first-aid treatment, including artificial respiration.

c. Permit no one to approach without first giving warning of the dangers.

d. Stand where all personnel working on the equipment can be seen, and the main power switch can be reached easily.

e. Immediately disconnect power at the first sign of an emergency.

Compliance with technical orders. DO NOT use unauthorized directives, such as this CDC, for maintenance procedures. Instead, comply with all of the instructions contained in the equipment technical orders (TOs), manuals, and handbooks.

Personal jewelry. DO NOT wear rings, dog tags, wristwatches, or metal-rim glasses when working on electrical equipment or aircraft. Many fingers have been lost because an individual either refused or forgot to remove his ring while working on equipment.

Workbenches. Workbenches must be kept clean at all times. When voltage is applied to equipment being repaired or tested, other equipment and tools not essential to the test are to be removed from the bench. Metal, metal framed, or metal-legged workbenches used for repairing and testing of electrical/electronic equipment must be grounded to a low-resistance ground.

Equipment cleaning. Use only approved fire-resistant solvents for cleaning electrical/electronic equipment. Provide adequate ventilation whenever you use solvents for equipment cleaning. Be careful not to breathe the solvent fumes and do not allow too much of the liquid to come in contact with your skin. Do not rub your eyes when any cleaning solvent is on your hands.

Exercises (054):

1. When you are working on a low-voltage system, how should it be treated?

2. Name one treacherous feature of electricity.

3. List five primary responsibilities of a safety observer.

4. What type of solvents should be used to clean electrical/electronic equipment?

055. Cite the harmful effects of electrical shock on the human body.

Electrical Shock. For those who work with voltages and currents, ignorance of the true nature of shock is dangerous. Knowing what actually happens is the first step toward taking the proper precautions. In the case of electrical shock, there are too many misconceptions.

Fact or Fiction? Let's examine the following examples to separate fact from fiction.

Example 1:

Fiction: Small currents are always less harmful than large ones
Fact: For obvious reasons, the exact intensity of current that will cause death in a human being is not easy to determine. However, much research has been conducted in this direction.

You should be aware that a very small current, as little as 0.015 ampere, can cause muscle paralysis. Once this occurs, the victim can do nothing to free himself or herself. However, in some cases, muscles contract with enough violence to "throw" the victim. This of course, may cause secondary injuries if you were to hit something in your flight; it also may be the means of saving your life. A larger current would be more likely to do this than a smaller one.

Currents of 0.07 to 0.09 ampere at 60 Hz AC can cause death by ventricular fibrillation if they pass through the chest. However, much lower currents can also be fatal. A current of only 0.015 ampere passing directly through the chest can render you incapable of releasing your from the circuit, while simultaneously paralyzing the muscles of the diaphragm needed in breathing. Unless you are released from the curcuit with outside help, you die from suffocation even though the heart and respiratory centers are not directly affected.

Example 2:

Fiction: Low voltages are not lethal
Fact: The amount of current for a given applied voltage, of course, depends on resistance, and the resistance of the human body varies widely.

Resistance depends, among other things, upon the path of current, the duration of current flow, the condition of the skin, and the area of contact. Normally the skin has a high resistance to current flow. When the skin is broken, charred, or wet with perspiration, its resistance is so low that 25 volts could produce sufficient current to cause death. Confirming this, there are cases on record of deaths caused by 32-volt farm lighting systems. Yet, under more favorable conditions, the 120-volt house lighting system could cause only a tingle.

In addition to the voltage and current magnitudes, the current body paths are also important. Any route involving the heart or brain is extremely dangerous. Voltage from one hand to the other sends a large proportion of the current through the heart. Here's a warning that should be known to all that work around electrical circuits: Keep one hand behind your back when working near a live current where the voltage is 600 volts or more!

Example 3:

Fiction: There are no harmful aftereffects if you survive a shock.
Fact: If you suffer a shock and have sustained no apparent injury, it may not mean that your troubles are over.

Electrical shock sometimes damages nerve tissue. This may cause a wasting away of muscle—a slow, progressive disturbance that may not become evident for weeks or even months. Other delayed effects may produce personality changes, amnesia, mental inertia, blood vessel diseases, cataracts, destruction of the pancreatic tissues, and heart conditions. This sounds pretty horrifying, doesn't it? Remember it when you are tempted to ignore good safety practices.

Exercises (055):

1. Tell how the body is sometimes "thrown" away from contact with an electrical circuit.

2. How can a current of 0.015 ampere can cause death?

3. List the conditions of the body skin which could cause contact with extremely low voltages to prove fatal.

4. Why should you keep one hand behind your back when working near a "live" circuit of 600 volts or more?

5. Even though you survive an initial shock, what harmful aftereffects could occur over a long period of time?

056. List electrical safety equipment used in electrical shops.

AFSOH Standards for Electrical Shop Safety Equipment. there are many Air Force Occupational Safety and Health Program (AFOSH) standards that apply to you as an electrician and the shp where you work. We mention here some of the safety equipment required in electrical shops where high voltage is present.

Variations in the equipment depend on local conditions. The equipment may be displayed on a board or stored in a cabinet, however, it must be situated in a conspicuous and prominent location at each site, well marked, and readily accessible to personnel. If a board is used, recommended size is 4′ x 4′ x 1/2″. Coloring is not mandatory; however, the recommended color is a dark green background with white letters and border. In each case, the color should be conspicuous against the background coloration of the particular facility. Safety equipment must consist of:

a. The safety operating instructions (OI) for the particular site.

b. Cardiopulmonary resuscitation (CPR) instructions.

c. Emergency phone numbers (preferably luminescent).

d. First-aid kit (as required by base medical services).

e. Hook with hardwood handle, 3-inch to 4-inch round end screen hook, with a 5-foot hardwood handle 1½ inches

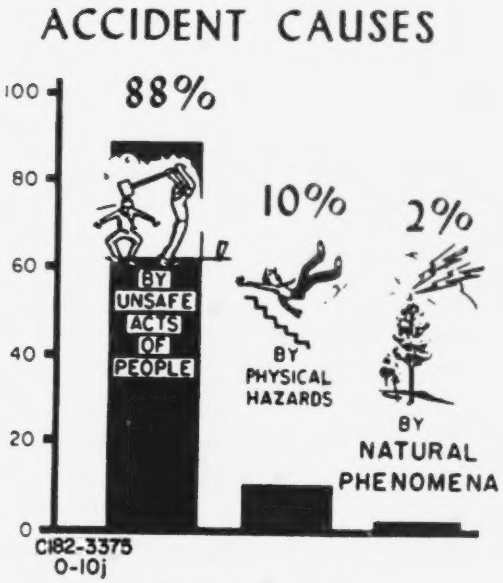


Figure 3–4. Accident causes.

in diameter. The hook should not part from the handle with a 300-pound pull. In lieu of this, a wooden cane obtained through medical supply channels may be used. Another (but more expensive) item that may be used is a pike pole, stock number 5120–00–243–2766 (contained in GSA catalog).

f. Rope (preferably 15′ x 1/2″ hemp).

g. Insulated fuse pullers (when required).

h. Flashlight (nonmetallic case). This should be in operating condition, marked with luminescent tape for easy location in the dark.

i. Grounding stick (shorting stick).

Optional items are:

a. Snakebite kit.

b. Wool blanket.

c. Insulating blanket.

Exercises (056):

1. Briefly list the mandatory items found on an electrical shop safety board.

2. What are three optional items on the safety board?

057. Cite common causes of accidents and identify accident prevention controls.

Accidents are Preventable. Accidents do not happen without cause. Identification, isolation, and control of these causes are the underlying principles of all accident-prevention techniques. Even natural elements can be controlled to some extent. Accidents caused by such phenomena as lightning, storms, and floods are extremely difficult to prevent; but the effects of these can be minimized. For example, aircraft can be secured when strong winds are expected. Accidents due to nature, estimated at only about 2 percent of all accidents, are classified under the term natural phenomena (see fig. 3-4).

Theoretically, preventable accidents can be traced to antecedents originating in the heredity and environment of individuals. These tendencies manifest themselves in personal characteristics that cause an individual to perform an unsafe act or to overlook, or tolerate an unsafe condition that can result in an accident. The injuries, property damage, and loss of combat capability that follow complete the costly sequence. The detection and elimination of such characteristics as inattentiveness, excitability, impatience, and stubbornness are normally extremely difficult to spot. On the other hand, the elimination of unsafe acts and conditions is a relatively simple and effective means of accident prevention.

Unsafe Acts and Conditions. Unsafe acts and conditions may be considered the direct cause of any accident. When this direct cause is removed, the sequence is interrupted, and the accident cannot happen. Usually, unsafe acts and conditions can be anticipated, readily identified, and immediately eliminated. Because of this, practical accident prevention measures are designed to prevent or eliminate direct causes, and suitable controls have been developed for this purpose.

To be completely effective, accident prevention controls cannot be applied "hit or miss." If engineering education, training, supervision, and enforcement measures are based on factual evidence and directed toward the solution of specific problems, controls can be adequately applied.

Safety Education. A ground safety program is no better than its educational efforts. When you teach a person the right way to do something, you are also teaching the safe way. Because this is true, the *safety* factor often loses its identity when it is part of other instruction—the supervisor, airman, or employee fails to grasp the importance of the fact that people cause accidents and that accidents can be controlled. Safety can, and should, be integrated effectively with job training.

Application. Adequate safety education with enforcement is the most effective way of preventing accidents. The application of safety education is extremely important in preventing accidents that cannot be offset by engineering, supervision, or enforcement measures; particularly those accidents occurring during off duty hours. The most important effect of safety education is to develop in an individual a safety consciousness which functions constantly. Because of the large number of off-duty accidents, safety education is not merely desirable but mandatory to any safety program. A "post mortem" safety program stressing corrective action after an accident has happened is not at all effective unless all possible preventive measures have been taken beforehand. Each accident results from some deficiency in the safety program. Most often, the deficiency is caused by a person, and it can be eliminated by adequate methods of safety education.

Methods. Educational methods should be based on sound and recognized techniques. Some of the fundamental principles of safety education are these:

a. Schedule your safety meetings so that they conflict as little as possible with normal operational routine.

b. Tailor the instruction to meet the individual needs of your group.

c. Use visual aids such as mockups, moving pictures, slides, charts, diagrams, and the chalkboard to their fullest extent.

d. Use all publicity media, including safety contests, and awards to keep accident prevention fundamentals fresh in the mind of everyone.

Safety Training. This is a specialized form of education to prepare an individual to work safely with minimum supervision. To insure maximum safety, each airman should receive specific instruction about job to insure full awareness of the dangers involved and the safety practices to offset them. Safety training in the Air Force is divided into four major phases:

a. Orientation.
b. Supervisors' training.
c. Job training.
d. General training.

Orientation. Safety orientation of new airmen and employees is an effective tool of accident prevention, because it creates lasting impressions during the initial contacts of the airman with the new job, organization, or activity. This is an excellent time to acquaint airmen with the local policy on accident prevention and explain what is expected of them as new members of the team.

Supervisors' training. Supervisors must be given formal safety training for two basic reasons: (1) these key individuals must have a working knowledge of the fundamentals of accident prevention if they are to carry out their assigned responsibilities of determining and eliminating hazards; and (2) supervisors must have accident prevention "know how" if they are to train their personnel successfully in on-the-job safety.

Sustained job safety training. This training phase helps develop safe, efficient employees and crewmembers. Training should not only be done initially but on a recurring basis to meet the operational changes, and to maintain a high degree of safety consciousness. Personal interviews by the supervisor and 5-minute "standup" talks are the most frequent methods. This type of continuous training is necessary if safety is to keep its identity in the vast quantity of other instructions received by personnel. Important steps in this training are these:

a. Analyze the job. Each job for which training is given should be broken down and analzyed in detail, with its specific dangers designated.

b. Establish safe practices. Where it can be done, hazards should be eliminated immediately. Safe practices should be established for protection from remaining hazards.

c. Analyze the individual. Individuals under training should be studied with reference to their personal qualifications and characteristics as they apply to their job; this is necessary to determine if additional or special training is necessary.

d. Plan the training. To maintain the worker's interest, plan the worker's instruction. Stress the importance of safe habits and practices.

General training. Supervisors and trainers must inform their personnel of all existing safety hazards. To accomplish this task, they may use standup talks, posters, newspapers, radio films, and informative tours. The training program is one of the most widely and effectively used programs in the area of safety.

Exercises (057):

1. What classification is given to accidents caused by such conditions as lightning, storms, and floods?

2. List the personal characteristics that are difficult to detect and counteract.

3. What is considered to be the direct cause of any accident?

4. How can accident prevention controls be applied adequately?

5. Cite the most important goal of safety education.

6. List briefly four fundamental principles of safety education.

7. List the four major phases of safety training in the Air Force.

8. Why must supervisors be given formal safety training?

9. What are the two most frequent methods employed in sustained job safety training?

058. State procedures to follow when accidents occur involving electrical shock.

Rescue Techniques. What should be done if you see someone rendered unconscious by electricity? Every person who works near electrical equipment should be acquainted with rescue techniques. The first step in rescuing a person from live wires is to break the connection between the victim and the circuit. If possible, do this by turning the power off. The next best thing to do, if you can't turn the power off, is to remove the victim from the circuit without endangering yourself. Do this by using a wooden board, rope, or some other nonconducting object. As soon as you can safely touch the victim, apply artificial respiration (preferably mouth-to-mouth). Closed cardiac massage is an important measure that may be needed; however, you should use only approved procedures for both life-saving aids.

Speed is essential. Any delay greatly reduces the chances of recovery. Over 70 percent of those receiving artificial respiration within 3 minutes recover. Just 1 more minute of delay drops the figure to 58 percent. If there is no heart or respiratory action, and treatment is delayed 5 minutes, death is virtually certain. If you are alone, do not take time to go for help. Start artificial respiration and/or closed cardiac massage, as required, immediately. If the person can be saved, you can do it as well as anyone. Don't stop, even if the victim appears to be dead. In some cases, 8 hours have elapsed before the victim responded. Only a physician should decide whether or not the person is dead. Above all, don't let the victim be YOU or one of your fellow airmen.

Exercises (058):

1. State the first step to take when a person is rendered unconscious by electrical shock.

2. How should a victim be removed from a voltage source?

3. What is the most essential factor regarding aid to a shock victim?

4. Which first-aid procedure should be started immediately following electrical shock?

5. When should artificial respiration be stopped?

059. State safe work habits that will help prevent injury to personnel and prevent fires.

Fire Prevention and Good Housekeeping. One of the first steps in any safety program is good housekeeping. Keep your shop or work area clean and uncluttered. This lessens the possibility of anyone tripping over an out-of-place toolbox or extension cord, or slipping on some spilled oil. Other items that may find their way into your work area are soft drink bottles. They should be kept in the break area and in proper containers. Broken glass is one of the most dangerous of objects.

Most shops have a tool board on which special tools are available to all who need them. Keep these tools in place. Other tools are large and could more properly be classified as machines. Whatever you call these heavy objects, get help to move them. A strained back is a large price to pay for indulging in a moment of false pride.

Ventilation and Lighting. Good ventilation is conducive to good work. Ventilation is necessary for the health and safety of personnel. You will find that your work output will drop off considerably if you are uncomfortable (hot or cold) or if you lack fresh air. If the air is dusty in your shop or if fumes are present, tell your supervisor so the situation can be corrected. Proper lighting is another prerequisite for doing good work. Definite standards have been set up by the Air Force to provide the proper lighting standards for all installations. These standards must be followed. Good lighting and good housekeeping both help to eliminate accidents.

Fire Prevention. Fire prevention is equally as important as accident prevention and goes hand in hand with good housekeeping. Many fires are caused by careless acts such as an oily rag thrown in a trash can. This is excellent material for a serious fire. Poor storage practices, especially when flammable materials are involved, have caused too many avoidable fires.

Below are a few precautions that you should observe in connection with fire prevention if we are to have fire-safe shops. You can add to the list from your own experience:

- Do not allow oily rags to accumulate.
- Observe the signs in the NO SMOKING areas.
- Never allow your clothing to become saturated with flammables. If this does happen, you must change your clothing as soon as possible.
- Do not permit flammable fuels to be stored in open containers.
- Never deposit cigarettes or matches in wastebaskets.

Exercises (059):

1. What is the first step in a safety program?

2. Name four precautions you should observe in shop housekeeping to prevent fires.

060. Distinguish among the types of fires and state the components of a fire

Composition of Fire. Fire is the result of a chemical reaction between three or more components which causes combustion. The three things necessary for combustion to take place are fuel, oxygen, and heat.

Before you can have a fire, you must have something that will burn—that something is called the fuel. In order for combustion to occur, you must also have oxygen, which is usually supplied from the earth's atmosphere. But fuel and oxygen alone are not enough. You must also have heat. When fuel is hot and sufficient oxygen is present, fire will result.

This leads us to the main point concerning combustion. If you take away any one of the three things necessary for combustion, you will put out the fire. Oxygen and heat alone are not enough to produce a fire; you need fuel to burn. Similarly, a fire cannot exist with just oxygen and fuel unless the fuel is hot enough to burn. Remember, remove any one of the three elements and the fire will die out.

Types of Fires. There are four types of fires. They are designated as types A, B, C, and D. These types of fires are listed below. Remember what each type consists of:

Type A–Wood, trash, paper, and waste.

Type B—Gasoline, oil, oil-based material, varnishes, etc.

Type C—Electrical wiring and components.

Type D—Magnesium, titanium, sodium, and potassium.

Exercises (060):

1. Name the three components necessary for a fire.

2. List the materials that are classed as a type A fire.

3. What is the class of an electrical fire?

061. Cite advantages and disadvantages of fire extinguishers and differentiate among their uses.

Fire Extinguishers. Fire extinguishers are tools that we don't normally use everyday. You'll find them hanging on walls in rooms and hallways and close to exits. They are to be used to put out small fires, not to play with and squirt your buddies or to cool beer. If a fire does not exist, then you have NO reason to handle the extinguisher—so leave it alone! This cannot be overemphasized. There is nothing worse than grabbing a fire extinguisher to put out a small fire only discover it is empty. The small fire can become a major one with loss in property and possible loss of life. You'll notice that we mentioned putting out a small fire. That is the only purpose for these extinguishers. They are not effective on large fires. Regardless of the size of the fire, CALL THE FIRE DEPARTMENT. All you should try to do is contain a fire.

Water extinguishers. Basically, there are two types of water extinguishers, pump and pressure. The pump type has an opening on the top and is filled with regular tap water and antifreeze. This is the only type of extinguisher that you are allowed to service. It has a hose which you aim at the base of the fire; at the same time, you must pump the handle that is located on the top of the extinguisher. This type is seldom found because it is being replaced; however, you should know how to use it.

The other is the water-pressure type. All you have to do is to point the hose at the base of the fire and squeeze the lever. It will squirt a stream of water from 6 to 10 feet. These are usually filled with an antifreeze mixture in cold climates. These water extinguishers are used on type A fires.

The advantages of this type of extinguisher are that it is easy to fill and to charge. It is relatively inexpensive for the job that it does in putting out small fires. The main disadvantage of this type of extinguisher is its limited use. It is effective only on type A fires of paper and wood. It should never be used on electrical, grease, or paint fires.

Carbon-dioxide extinguishers. This type of extinguisher should be used on type B fires. It extinguishes fires by smothering rather than by cooling.

The carbon-dioxide extinguisher is used the same way as the water-pressure extinguisher. The main difference is that you will not use the carbon-dioxide (CO_2) on wood and paper fires. This type is used mainly on petroleum products. If this type were to be used on paper or wood, the pressure would blow the fire to other locations. CO_2 smothers a fire and should be used in short blasts aimed at the base of the fire.

The advantages of the CO_2 extinguisher are that it puts a fire out in a short time—but again remember, only a small fire. CO_2 leaves no residue and will not freeze. It can also be used on electrical fires. About the only disadvantage is that it should not be used in a small, closed room as carbon dioxide can kill if you do not have proper ventilation.

Dry-chemical extinguishers. These extinguishers must not be confused with the dry-powder kind. Dry-chemical extinguishers (sodium and potassium-bicarbonate based) are designed for use on type B and type C fires. Multipurpose (ammonium phosphate) dry-chemical extinguishers are designed for use on type A, B, and type C fires.

Dry-powder extinguisher. Extinguishers of the dry-powder type are designed for use on type D fires only. The agents used in these extinguishers may be in a powder or granule form. Using these agents on the wrong type of metal fire may result in a serious explosion, release of toxic gases, or both, thus endangering the user and others. You will find that one agent can be used on several types of metal fires while another agent can be used only on one specific type of metal fire.

The advantages are that it is quick to extinguish the flame and the dry chemicals will not freeze, so it can be left in the cold. It does leave a residue which is the main disadvantage.

Regardless of how much or how little chemical is used from any type of fire extinguisher, it must be recharged before it can be considered serviceable. The reason is that if a fire extinguisher is used, you have no way of knowing how long it was used and how much of its chemicals are left to fight another fire. So, consider a used fire extinguisher as an empty fire extinguisher, and get it recharged at the base fire station immediately after use.

Exercises (061):

1. Name three basic types of extinguishers and list the advantages and disadvantages of each.

2. Which type(s) of fire extinguisher(s) would you use on an oil fire?

3. Why is a carbon-dioxide extinguisher unsafe to use on wood or paper fires?

Handtools and Electrical Hardware

IN YOUR DUTIES as an aircraft electrical systems specialist, a large amount of your time will be spent working with what we call the "nuts and bolts" of your career field. "Nuts and bolts," as it is used here, means the structural hardware used to mount and secure electrical components, wiring and connectors, small electrical components, and the handtools used in electrical repair. This chapter covers general electrical maintenance, an area that every aircraft electrical systems specialist must know in order to make acceptable aircraft repairs. When incorrect maintenance is pointed out by the inspector, it is usually in this area. The use of the wrong crimping tools, nuts, washers, terminal blocks, or poor soldering joints is a very serious matter and should not be taken lightly. Study the material in this chapter well and make sure you use the technical order directives and procedures as you make electrical repairs.

4-1. Miscellaneous Aircraft Structural Hardware

All specialists, whether mechanical, electronic, or electrical are involved in the removal or replacement of system components. A malfunctioning component may require replacement, or a component may need to be removed in order to obtain access to the area of the malfunction. Components, wire bundles, etc., are mounted on the aircraft with structural hardware of which you should have a working knowledge.

062. State criteria for using bolts, nuts, and washers.

Aircraft components are mounted with screws, bolts, or special fasteners. In this objective, we discuss how special bolts are identified, how to determine correct size of bolts to use, and examine the stresses applied to bolts.

Bolts. Most of the bolts used on aircraft are standard aircraft bolts. In certain cases, aircraft manufacturers are required to make bolts of special dimensions or of greater strength than the standard type. Such bolts are made for particular applications, and it is of extreme importance to use like bolts in replacement. Such special bolts are identified by the letter S on the bolthead. Standard aircraft bolts are designed for general application, and are made of cadmium or zinc-plated, corrosion-resistant steel or anodized aluminum alloy. The bolts used in some component installations are the same as standard aircraft machine bolts, except that the deeper heads are drilled to receive safety wire for securing.

Sized for installation. During this study we are discussing a bolt, nut, washer, and lockwasher assembly as shown in figure 4-1. In most aircraft usage, the diameter of the bolt's grip length should be just slightly smaller than the hole or holes in the material it is holding together. Boltholes that are oversized or elongated do not carry their share of the load, and the held-together material is likely to shift under stress and vibration. After the correct size diameter bolt has been determined, the length of the shank and the grip length must be considered. Again referring to figure 4-1, notice that the grip length starts from the underhead bearing surface and terminates at the point of the innermost thread and that the shank includes the grip length plus the threads.

Now that you know what the grip length of the bolt is, it follows that the material held together by the bolt is called the *grip*. For a good installation the grip length must be a few thousands of an inch shorter than the actual material (grip). By looking at figure 4-1 you can visualize that with too small an amount of material on the bolts grip length, the nuts would be up against its last thread, and the material would not be held tight. If the bolt's grip length is just a little too long, washers are sometimes placed under the nut or bolthead to effectively increase the size of the material. This then permits the bolt and nut to firmly hold the material in place.

Going to the other extreme, bolt installations which involve self-locking or plain nuts should normally have at least two complete threads protruding through the nut. These two threads may be the chamfered end of the bolt; i.e, the first two threads which are tapered smaller than the rest of the threads. If the two threads are not protruding through the nut, a longer bolt must be used.

Selecting the correct bolt assembly for an installation is very important, but this is only half the job. The bolt assembly must be properly torqued for the job to be complete. Torque is the turning effort or force required to apply tension to a nut or nut and bolt assembly or the act of tightening a fastener assembly to a specific value. Torque is expressed in inch-pounds or foot-pounds.

Torque procedures. When a bolt assembly is tightened or torqued, it takes two stresses: (1) torsion, and (2) tension. Torsion is the force applied to overcome friction, and tension is the desired stress that remains after the assembly is tightened. Standard torque charts have been established for average-dry unplated conditions, but surface variation such as thread roughness, paint, lubrication, or plating may alter these values considerably. Because of these surface

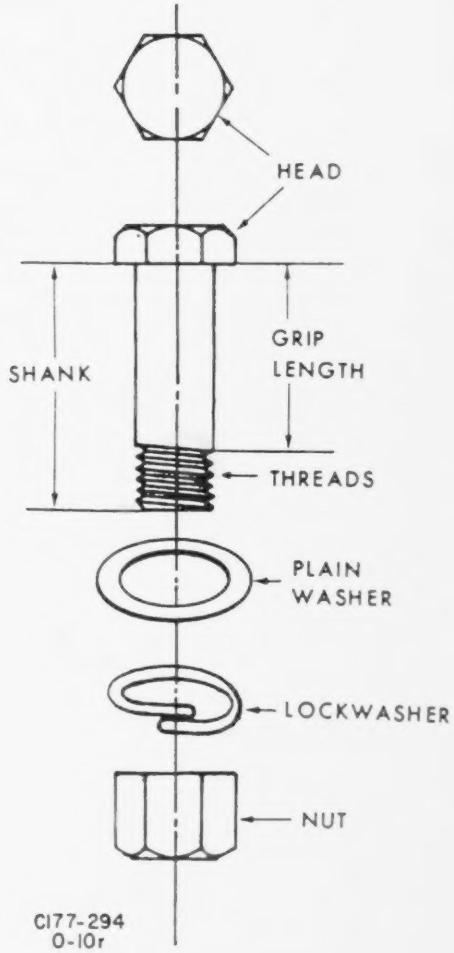


Figure 4-1. Nut-and-bolt assembly.

variables, torque values that are included in a specific end-item technical order should always be used in lieu of values given in standard charts, or general hardware technical orders.

Correct torquing of bolt assemblies cannot be overstressed. Many man-hours are lost and lengthy job delays are caused by improper bolt assembly torquing. When repairmen disregard torque values, bolts may be twisted or broken. Torque values given in technical orders are based on bolts or stud specific characteristics, and it takes into consideration other conditions involved in particular installations. These values and other directives should be closely followed.

Nuts. The purpose of any nut is to properly load (tighten) the bolted assembly. To do this, there must be a mating of the threads; therefore, the nut must have the same type of threads as the bolt. A nut with the wrong threads for the bolt will strip away the threads and will improperly load the bolted assembly.

Most aircraft use self-locking nuts to mount components to the aircraft structure and also to connect electrical leads on terminal block studs. Self-locking nuts are of two major types—the prevailing torque type and the free-spinning type. The free-spinning type turns freely until seated, then further tightening results in a locking action. The most widely used, prevailing torque type nut requires wrenching throughout the entire cycle after the bolt has engaged the frictional part of the nut. Nonmetallic prevailing torque nuts have a nylon insert of a smaller inside diameter than the bolt's major diameter. This exerts a compressive locking force against the bolt. If nonmetallic self-locking nuts are reused, they must be checked to see that the locking insert has not lost its locking friction or become brittle. They are not to be used in areas where they are subjected to temperatures in excess of 250° Fahrenheit (approximately 112° Centigrade).

Slotted or beam-prevailing torque self-locking nuts have a tapered and slotted (or split) top. Each portion between the slots acts as a beam and is depressed inward to form a functional locking element.

Washers. There are many types and varieties of washers that are used in a variety of applications on today's modern weapons systems. The most common types are plain washers, lockwashers, and special washers.

Plain washers. Plain washers are used under nuts to provide a smooth bearing surface, to act as shims in obtaining the correct relationship between the threads and the end of the bolt or under lockwashers to prevent damage to surfaces of soft material. (Lockwashers should never be used on soft metal surfaces without the aid of a plain washer to prevent damage of material.)

Plain washers are used to prevent corrosion caused by dissimilar metal contacting surfaces. Aluminum-alloy washers should be used with steel bolts on aluminum-alloy parts, and steel washers used on steel parts. In cases where high torque is required, steel washers should be used regardless of whether the part is steel or aluminum.

Lockwashers. Lockwashers are used with plain nuts when self-locking nuts are not applicable. The spring action of the lockwasher provides extra resistance to keep the nut from turning in a loosening direction. Lockwashers are not to be used on an aircraft's primary structure, secondary structure, superstructure, or on accessories where failure might result in damage or danger to the aircraft or personnel. Lockwashers are not to be used where their failure would permit leakage, or on exposed surfaces subject to airflow; they should not be installed in places where they will be subject to corrosive conditions nor in places where they must be removed frequently.

Special washers. There are many types and varieties of special washers used for a multiplicity of applications. Some are designed to be used for bolts which are installed at an angle to the surface, or for taper pins, and to indicate torque applied to a tightened nut.

Exercises (062):

1. How are special bolts usually identified?

2. What should be considered when selecting the shank and grip length of a bolt?

3. What inspection should be performed on a nonmetallic self-locking nut before it is reused?

4. Name situations where plain washers should be used.

5. Where should lockwashers not be used?

063. Determine which type of safety device to use on aircraft electrical components.

Aircraft vibration tends to loosen or alter adjustment of various parts, such as electrical connectors, nuts, bolts, turnbuckles, and screws. Therefore, parts that are intended for disassembly or adjustment are safetied by an auxiliary device or a self-locking feature. Self-locking nuts are used extensively throughout aircraft, but when self-locking nuts are not feasible, other safetying methods.

Cotter Pins. Cotter pins may be used to secure such items as bolts, screws, pins, and shafts. Their use is often favorable over other safety methods because they can be removed and installed quickly. The diameter of the cotter pin selected for any application should be the largest size that will fit, and it should be consistent with the diameter of the cotter pinhole and/or the slots in the nut (see fig. 4-2).

Safety Wire. Safety wire is a very common, if not the most commonly used safetying device. It is used to secure screws, bolts, nuts, snaprings, caps, valves, turnbuckles, electrical connectors, and emergency devices. Safety wire is made of zinc-coated soft steel, aluminum, or copper. The size (diameter) of safety wire is given in thousandths of an inch. In your area of aircraft maintenance you will most often use steel wire of .020 or .032 of an inch in diameter; however, in cases of sealing emergency devices, .020 of an inch copper wire will be used.

Double-twist. The double-twist method of safety-wiring is the most common method used, but in some cases the single-wire method may be authorized. When using the double-twist method, the safety wire should be placed through the drilled hole and twisted in a manner to insure that the loop around the bolthead or nut stays down (see fig. 4-3). The wire is to be pulled in a direction away from the bolt or nut so that it will resist any loosening of the bolt or nut which it is securing. The wire may be twisted by hand, (approximately 6 to 8 turns per inch) except for the final few twists, which should be made with pliers to properly secure the wire ends. Cut off the part of the wire gripped by the pliers to remove rough edges. As a safety measure, you must wear eye protection when snipping off the ends of safety wire. A special tool used for twisting safety wire simplifies and speeds up the job. Take extreme when twisting the wire to insure that it is tight but not stressed to the point where breakage might occur under a slight load or vibration. Make a pigtail of 1/4 to 1/2 inch (3 to 6 twists) at the end of the twisted wire. This pigtail must also be bent back or under to prevent it from injuring personnel.

Connector safety-wiring. Safety-wiring electrical connectors will be a large part of your job. Figure 4-4 gives some of the various types of safetying that may be encountered on these connectors. Most of the same procedures that apply to the safetying of a bolt or nut will also apply to connectors. One thing you should remember is that .020 wire is used in the securing of connector coupling rings unless other wise specified by a specific technical order. Larger wire can break out the hole in the coupling ring. New safety wire should always be used regardless of what you are safetying. Make sure the wire does not become kinked or nicked during the twisting operation. Mounting fillister head screws should not be backed off or overtorqued in order to align holes for safety wiring. When the coupling ring is secured to the structure, the attaching point is not to be more than 6 inches from the connector.

Single-wire safety-wiring. The single-wire method of safety-wiring may be used on screws in a closely spaced group or pattern, such as screws located in a close triangle, square, rectangle, or circle. Figure 4-5 shows three examples of the use of the single-wire method. Notice that the wire is positioned so as to keep the screw for loosing. The pigtail should be twisted the last few turns with pliers is, and then the area held by the pliers to be cut off. All pigtails should be bent back to protect personnel.

Emergency device safety-wired. Emergency devices usually are safety-wired using .020 copper wire, and by the single-wire safetying method; however, the TO should be referenced for each task. The safety wire acts as a seal on emergency equipment such as first aid kits, portable fire extinguishers, emergency valves, and oxygen regulators. A

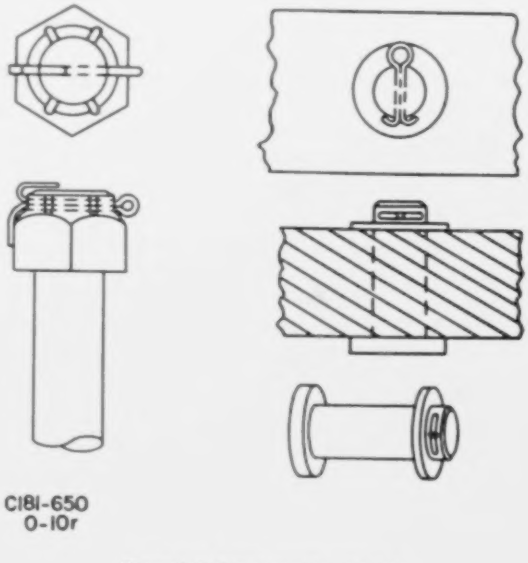
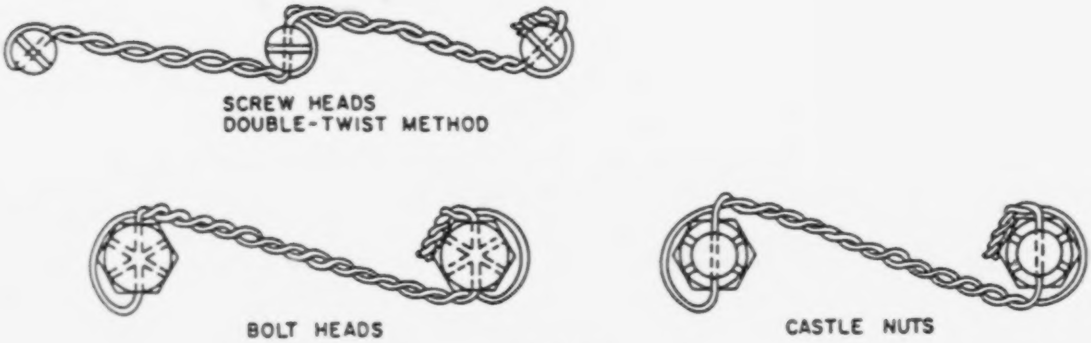


Figure 4-2. Securing with cotter pins.

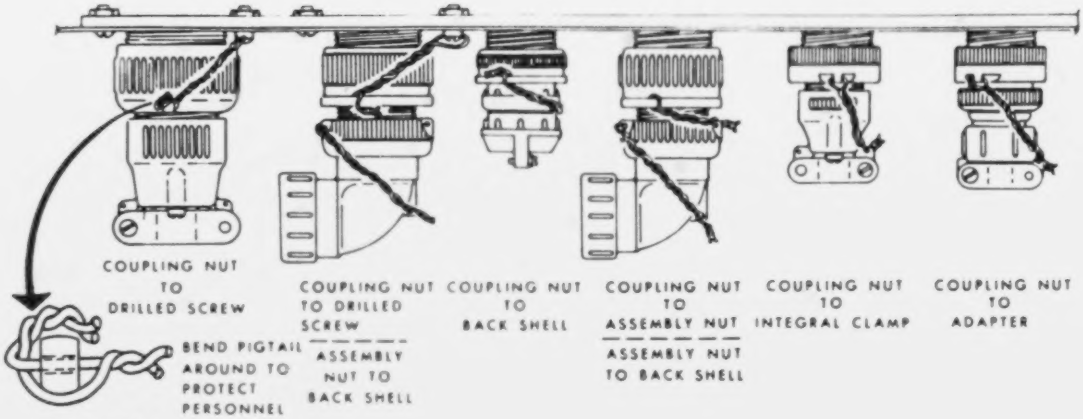

SCREW HEADS
DOUBLE-TWIST METHOD
BOLT HEADS
CASTLE NUTS

NOTE

THE SAFETYWIRE IS SHOWN INSTALLED FOR RIGHT-HAND THREADS. THE SAFETYWIRE IS ROUTED IN THE OPPOSITE DIRECTION FOR LEFT-HAND THREADS.

C177-295
0-10r

Figure 4-3. Safetying screws, nuts, and bolts.


COUPLING NUT
TO
DRILLED SCREW
COUPLING NUT
TO DRILLED
SCREW
ASSEMBLY
NUT TO
BACK SHELL
COUPLING NUT
TO
BACK SHELL
COUPLING NUT
TO
ASSEMBLY NUT
ASSEMBLY NUT
TO BACK SHELL
COUPLING NUT
TO
INTEGRAL CLAMP
COUPLING NUT
TO
ADAPTER
BEND PIGTAIL
AROUND TO
PROTECT
PERSONNEL

C177-296
0-10r

Figure 4-4. Safetying connector plugs.

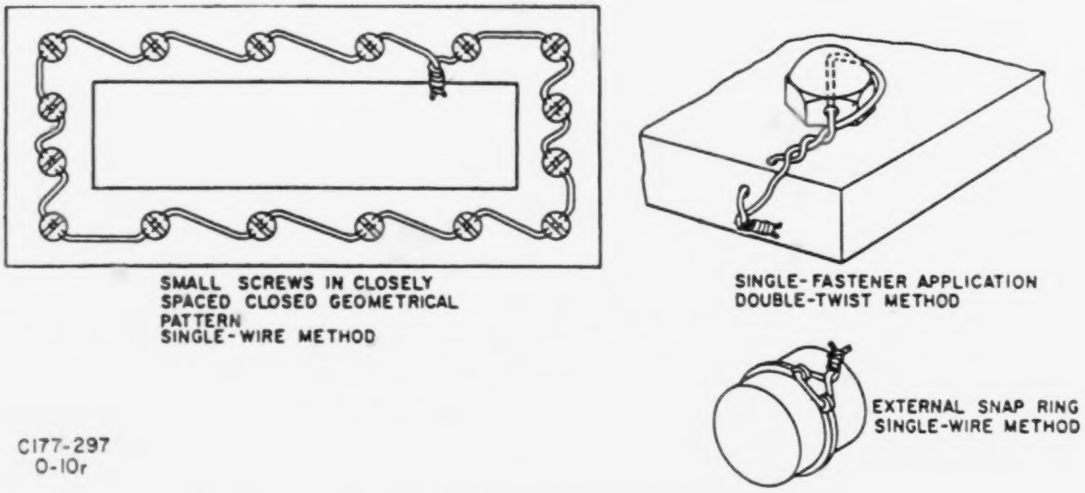

SMALL SCREWS IN CLOSELY SPACED CLOSED GEOMETRICAL PATTERN
SINGLE-WIRE METHOD
SINGLE-FASTENER APPLICATION
DOUBLE-TWIST METHOD
EXTERNAL SNAP RING
SINGLE-WIRE METHOD
C177-297
O-10r

Figure 4–5. Safetying using the single-wire method.

secure seal indicates that the component has not been opened. When using safety wire as a seal, take special care to assure that the safety will not slow or prevent emergency operation of the device (see fig. 4-6).

Exercises (063):

1. List the securing devices used on aircraft.

2. How is the correct diameter of cotter pins to be used in a job situation determined?

3. What size safety wire is usually used on electrical connectors?

4. How long should the pigtail be, and what other action should you take in regard to the pigtail?

5. Safety wire is twisted by hand with how many turns per inch?

6. When an electrical connector is safety-wired to the structure, what is the maximum distance the attachment point should be from the connector?

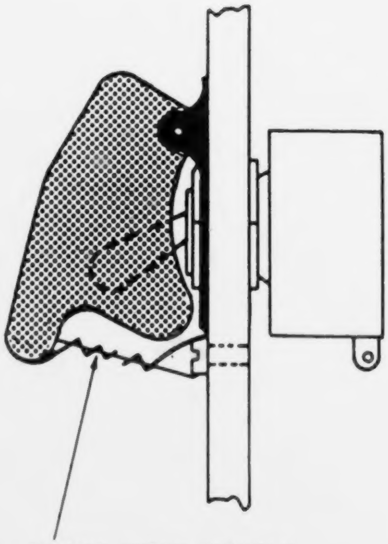

SEAL WIRE - DO NOT TWIST TIGHTLY
C182-3380
O-10r

Figure 4–6. Safetying emergency devices.

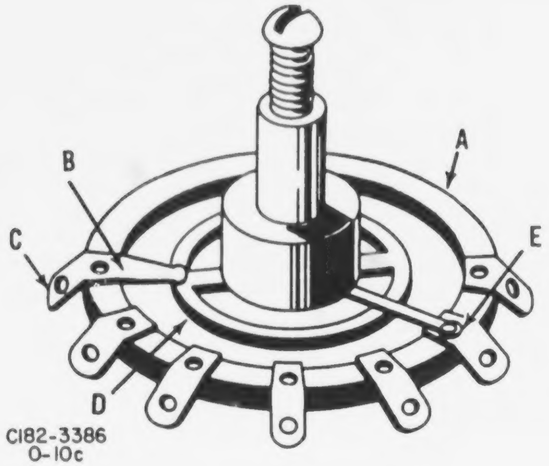


Figure 4-7. Rotary selector switch.

4-2. Common Electrical Control and Protective Devices

In electrical circuits there are a number of common components used for control and/or protection. Each circuit requires some method of control and must have a protective device.

064. List common electrical circuit control devices and state their purposes.

Switches. The proper functioning of electrical equipment depends upon its circuit control operation. Directing current to a particular piece of equipment is not a complicated feat. However, starting, stopping, varying, and reversing the current is another matter. For these purposes, we must have circuit controlling units if we are to control the various circuits found in the aircraft. The most common control unit is the simple on and off switch.

A switch may be described as a device used in an electrical circuit for making, breaking, or changing connections. Switches are rated in amperes and volts; the rating refers to the maximum voltage and current of the circuit in which the switch is to be used. When a switch is placed in a series circuit, all the current will pass through the switch. When the switch is open the circuit is open, and the applied voltage can be measured across the switch. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches generally use a snap action.

Classification. Many types and classifications of switches have been developed. The common designation is by the number of poles, throws, and positions they have. The number of poles indicates the number of terminals at which current can enter the switch. The throw of a switch signifies the number of circuits each blade or contactor can complete through the switch. The number of positions indicates the number of places at which the operating device (toggle, plunger, etc.,) will come to rest.

Positions. An example of the switch-position designation is a toggle switch that comes to rest at either of two positions—opening the circuit in one position and completing it in another. This is called a two-position switch. A toggle switch that is spring-loaded to the OFF position and must be held in the ON position to complete the circuit is called a momentary contact two-position switch. A toggle switch that will come to rest at any of three positions is called a three-position switch. A maximum-resistance reading of 1 ohm is allowed across the contact. More than this, the switch will be replaced.

Types. There are many types of switches utilized on today's modern aircraft. You should be familiar with the various types that are used. We will briefly discuss four types: pushbutton, rotary selector, mechanical, and thermal switches.

(1) *Pushbutton switches.* Pushbutton switches have one or more stationary contacts and one or more movable contacts. The movable contacts are attached to the pushbutton by an insulator. The switch is usually spring-loaded and is of the momentary contact type. These momentary switches have many uses; for example, they may be used as indicator-light checks, or for resetting a circuit. Occasionally you will find push-on and push-off types of switches, but these types are not very common.

(2) *Rotary selector switches.* A rotary selector switch may perform the functions of a number of switches. This is done, as shown in figure 4-7, by introducing power at the common terminal (C), which is mounted on the insulating ring (A). Power conducts from (C) through stationary contact (B) to the conducting ring (D). Thus, power is available at the movable contact (E) at all times. As the knob of a rotary selector switch is rotated, it opens one circuit and close another. The rings and contacts shown in figure 4-7 are collectively called wafers; and some rotary selector switches have several of these wafers mounted on a single shaft. By the addition of wafers, the switch can be made to operate as a large number of switches. These switches are generally referred to as selector switches. Ignition switches and voltmeter selector switches are typical examples.

(3) *Mechanical switches.* Mechanically operated switches are used for such purposes as landing-gear position indication, bomb-bay-door position indication, and various drive limit switches. Many of these sensitive snap-acting switches are found on aircraft. They are widely used because they are small, light, and very dependable. Although the term "microswitch" is frequently used in referring to all switches of this type, it is a manufacturer's trade name for its switches.

Switches of this type open or close a circuit with a very small movement of the tripping device (1/16 inch or less). They are usually of the pushbutton variety, and they generally depend upon one or more springs for their snap action. When the pressure of the plunger is removed, the spring again snaps the contact to the opposite position. This prepares the circuit for a new cycle. The versatility of the microswitch is tremendous because of the number of different mounting supports that have been devised for it.

(4) *Thermal switches.* A thermal switch usually incorporates a bimetallic strip that bends or snaps at a

desired temperature to actuate the switch. This type of switch is found in fire and overheat warning circuits. The operation of these switches is automatic whenever the preset temperature is reached. They may be used either to turn on a light for an indication or, in the case of an automatic control system, to start a chain of events for proper control.

Although the switch itself is relatively simple to check, it sometimes presents difficulty because it is located in an inaccessible place. After a visual inspection of the connections and the switch, a continuity test will indicate any malfunction. When the switch mechanism is found to be defective, it is usually removed and replaced since it is normally not reparable. Inclosed switches that are improperly sealed tend to allow moisture to condense in them. This causes shorts across the switch terminals, and the switch becomes defective. This difficulty may be corrected by carefully sealing any openings or using hermetically sealed switches. Hermetically sealed switches also prevent dust and dirt from reaching the contacts, thus the possibility of high-resistance open circuits is almost eliminated.

Some switch assemblies are equipped with adjustments that enable them to operate at a preset time or pressure. These adjustments should be made carefully, since damage may result if they are not accurate.

The various types of switches we have discussed are used for the direct control of a circuit. But there are cases when they are not feasible due to heavy current flow or simply because the circuit cannot be controlled directly. For these, we have devices appropriately called relays.

Relays. Relays used in aircraft electrical systems consist of a coil, a stationary iron core, fixed contacts, and movable contacts. A small current is passed through the coil, creating a magnetic field. The core, by magnetic attraction, pulls down the armature to which the contacts are attached and completes and electrical circuit to whatever device the relay is controlling. When the control circuit current is interrupted, the magnetic field about the coil collapses, and a spring forces the armature to return to its original position. This separates the contacts and opens the circuit to the device being controlled.

Relays are electromagnetically operated switches. They are classified according to their use as control, power, or sensing relays. Using relays saves space and weight in aircraft by permitting the use of small switches at remote stations. These switches allow the operator to control the flow of large amounts of current at other locations in the aircraft and, thereby, to eliminate the use of heavy power cables from one end of the aircraft to the other. Only lightweight control wires are connected to the control switches. Safety is also an important factor in using relays, since high power circuits can be kept out of the cockpit.

The power relays are the workhorses of the aircraft's electrical system. As such, they control the heavy power circuits. The function of a control relay is to take a relatively small amount of electrical power and use it either to signal or to control a large amount of power. Control relays, as their name implies, are frequently used in the control of other relays, although the small control relays have many other uses. Control relays can also be used in so-called lockout, interlock, or sensing relay positions. The automatic functioning circuits in our modern aircraft could not function without the use of combinations of different relays.

Many different types of relays are in general use today in various aircraft installations. The main differences between them are in operating voltages, current-carrying capacity, mounting, and control function (continuous or intermittent operation). The data plate of a new replacement relay should be closely checked before installation because the outward appearance can be very misleading. A relay, designed for intermittent operation, would not hold up if it were installed in a position calling for a continuous duty relay.

Variable Resistance Unit. Another control device is the variable-resistance unit. Variable-resistance devices are used extensively in aircraft to control the intensity of lights and speed of various small motors. They also vary the voltage (and hence the current) to an operating unit within a definite range of values. Variable resistance devices are classed as either rheostats or potentiometers, depending on the number of electrical contacts they have.

Rheostat. A rheostat, sometimes referred to as a variable resistor, consists of a circular insulator around which a resistance material has been placed. A movable contact that makes contact with the resistance material is mounted on a rotatable shaft. The shaft is mounted on a common center with insulating material between it and the rheostat. Circuit resistance is varied by the position of the movable contact. A knob is provided on some rheostats to allow easy adjustments, since many of them must be adjusted frequently. Other rheostats that are designed for basic circuit calibration generally require a screwdriver for adjustment. In this case, a locknut is loosened, and the contact is moved along the resistance strip until the desired resistance is obtained; at this point the locknut is tightened.

Rheostats are rated at normal temperatures in terms of maximum resistance, current, and power. This means that at normal temperature the values stated are (1) the top resistance available in the circuit, (2) the maximum current that the rheostat can carry, and (3) the maximum power that it can dissipate without overheating. You must consider all values when replacing a rheostat.

Potentiometers. Another variable-resistance device is the potentiometer. Most maintenance men refer to this device as a "pot." It is similar to the rheostat in external appearance. Potentiometers are rated in the same manner as rheostats; the ratings are resistance, current, and power. When they are used in circuits that require a variable resistance only, just one end connection and the movable contact are used. When a pot is used to adjust voltage (voltage divider), all three contacts are used. Input power may be applied across the resistance strip, and output power may be taken from one end of the resistance and the movable contact; its position determines the magnitude of the two voltages available at the ends of the resistance strip.

Exercises (064):

1. List four common electrical control devices used in aircraft.

2. What is the circuit function of the electrical switch?

3. How are switches rated?

4. What is meant when a toggle switch is identified as a single-pole, double-throw switch?

5. For what purposes are mechanically operated switches used in aircraft circuitry?

6. Where is a thermal switch most often found in aircraft circuitry?

7. Why are relays used in electrical control circuits?

8. What is the difference in use between the rheostat and the potentiometer?

065. List common electrical circuit protective devices and state their purposes.

Circuit-Protection Devices. Whereas it is very important to have circuit control devices, it is just as important to have a means to protect the circuit from current overload. Various types of circuit-protection devices are designed to protect wiring components and personnel when higher than normal current exists in a circuit. The electrical systems of an aircraft are protected from damage by fuses, circuit breakers, and current limiters. The simplest overcurrent protection device is the fuse.

Fuses. A fuse is a short length of wire or metal ribbon inside a suitably inclosed container. A current flow greater than the amount for which the fuse was designed causes the metal to heat and melt, opening the circuit that is being protected. A fuse is always placed in series with a circuit, so that it opens the circuit automatically. The current capacity of each fuse is marked on its side. In the case of the cartridge-type fuse, the current rating is marked on the ferrule (end cap). Also marked on this type fuse is an AG number (such as 3AG, 4AG) which indicates size and type of body—in this case, 3 amperes glass or 4 amperes glass. An AB number such as 15AB indicates 15 amperes bakelite.

Fuses are further classified as instantaneous or time-delay types. The instantaneous fuse will carry its rated current indefinitely, but it will quickly open the circuit when its rated capacity is exceeded by about 25 percent. Time-delay or "slow-blow" fuses (as they are generally called), are designed to stand overloads for some time before blowing. This feature is necessary to keep short-time surges, such as high-starting current for motors, from melting (blowing) the fuse. This time delay permits momentary high current without injuring the fuse, whereas continuous excessive current causes a rupture of the fuse.

Another consideration in the use of a fuse is the voltage rating. This rating refers to the maximum voltage that may be applied in the circuit in which the fuse is used. It is the voltage that the fuse construction can safely handle without arcing. If the fuse opens, the entire applied voltage of the circuit will appear across it. Therefore, the voltage rating of the fuse should be higher than the maximum circuit voltage.

Fuses used in aircraft are not the reusable or reparable type. A fuse used in an aircraft must be replaced with a new fuse after the defective equipment has been repaired. When a fuse has a glass body, a simple visual inspection will reveal whether the fuse is good or blown. With the bakelite, and sometimes even with the indicator type, it may be necessary to use an ohmmeter to determine if the fuse is good or blown.

Current limiters. Current limiters are devices somewhat similar to fuses; they are used in aircraft circuits that carry heavy currents. This circuit protector consists of a copper link with a weak section of calibrated dimensions. These sections blow or melt in the same manner as those of the cartridge fuse when the circuit becomes overloaded or shorted. To mount current limiters normally requires two properly insulated and spaced bolts or studs.

Current limiters are generally placed at both ends of a parallel bus feeder system. If a short occurs in the system, both current limiters will blow and completely isolate the fault. The remaining feeder leads will continue to supply power to the bus. It is important to replace current limiters with the proper type, since a time-delay type does not provide the proper protection in a circuit that requires instantaneous shutdown; and in some cases, an instantaneous shutdown may not be desirable. Circuit breakers. The most commonly used circuit protection device in the aircraft is the circuit breaker. It is designed to open the circuit under short-circuited or overloaded conditions without injury to itself. Thus, it performs the same function as the fuse or current limiter, but it has the advantage that it is capable of being reset and used again. In the same manner as the fuse, the circuit breaker is rated in amperes and voltage.

Circuit breakers used in aircraft are commonly categorized according to the way the circuit-breaking action is initiated; either thermal, magnetic, or thermomagnetic. Coverage here is directed primarily to thermal circuit breakers—since in this field, they are the most widely used. Thermal circuit breakers are further divided into subcategories by the manner in which they are reset. These subcategories are push-to-reset breaker, switch breaker, or push-pull breaker.

Push-to-reset breaker. A thermal push-to-reset breaker uses a bimetallic strip to perform the braking action. When the circuit is subjected to an excess of current, the increased heat causes unequal expansion of the two metals comprising the conducting strip, and the distortion bends the strip away from the electrical terminals. To reset the breaker, the operator merely pushes a button that forces the strip back onto the terminals. When this type of breaker is closed, the crewmember has no way of opening it.

Push-pull breaker. Realizing that you sometimes find it necessary to open the circuit breakers manually, the manufacturers designed a type of thermal breaker known as the push-pull breaker. These breakers are equipped with a red or white collar that surrounds the operating shaft. When the circuit breaker is open, the red or white collar that surrounds the operating shaft shows. When it is closed, the collar is inside the mechanism. This arrangement provides you with a quick way of visually checking any circuit breaker panel for a "popped" breaker. The push-pull circuit breakers are small, and their external projection from the panel is designed to redue the possibility of catching your clothing on them and thus accidentally interrupting an operating circuit.

Switch-type breaker. Another model of a thermal circuit breaker is called the switch type. The operator may open as well as close this kind of breaker. Externally, this breaker appears to be similar to a toggle switch. The toggle like mechanism is the resetter, which may also be used as a single-throw switch to turn the circuit on or off. Circuit breakers are further classified as trip-free or non-trip-free.

a. Non-trip-free breakers. You can hold the nontrip-free circuit breakers closed while a tripping condition exists. This type of breaker is generally used in circuits such as landing-gear or flap circuits, and constitutes an in-flight emergency if it becomes deenergized. These breakers should be held closed only in an emergency; and since this action is likely to change the calibration of the breaker, it should be replaced after being used in an emergency situation.

b. Trip-free breaker. The trip-free breaker is the more commonly used of the switch-type breaker. This circuit breaker cannot be held in the reset position.

On the ground, whenever a circuit breaker interrupts the circuit, you should check to determine the reason for the excessive current before any further attempt is made to operate the affected system. Sometimes circuit breakers become weak as a result of old age and of being tripped or reset so many times. These breakers should be replaced with new items.

Exercises (065):

1. List three different types of protective devices commonly used in an aircraft electrical system.

2. What type fuse would most likely be used in circuits that normally experience short current surges?

3. Current limiters are mostly used in what type circuits?

4. What is the advantage of using a regular circuit breaker as the circuit-protection device?

5. What is the purpose of using push-pull circuit breakers?

6. What type circuit breaker would most likely be used in an electrical circuit that may constitute an in-flight emergency?

7. How are fuses and circuit breakers rated?

4-3. Terminal, Splices, and Connectors

From time to time, it will become your duty to work with terminals and splices, so we will cover the basic information you need. We will also talk about connector plugs.

066. State methods of using terminals, splices, and connector plugs.

Terminal Installation. Aircraft wires are fastened to terminal studs (i.e., metal posts) with terminal lugs. The terminal lugs used in electrical wiring are of the soldered or crimped-on type. The terminal lugs used in repair work must be of the size and type specified on electrical wiring diagrams for the particular aircraft concerned. In special cases, such as on thermocouple connection, the soldering of splices and terminal lugs is limited to emergency repair.

The quality of soldered connections depends to a great extent upon the skill of the technician who has to control such factors as proper temperature, the correct type and quantity of flux, and cleanliness of all components. On the other hand, crimped-on terminal lugs attached to insulated terminal blocks, strips, or boards require much less technical skill to provide a highly dependable connection.

Most of the small copper wires (sizes No. 26 through 10) that we use are terminated with solderless, preinsulated, straight-copper, terminal lugs. The insulation is part of the terminal lug and extends past the barrel. This insulation covers a part of the wire insulation so we do not have to use an insulation sleeve.

Some preinsulated terminals can be used for more than one size of wire. The insulation is color coded and the range of sizes is marked on the tongue of the terminal.

Terminal blocks or boards provide a fast and convenient means of connecting terminal lugs inside junction boxes, and distribution panels. Terminal lugs should be installed on terminal boards so that any movement tightens the nut. Figure 4-8 shows the different ways in which this may be done. Part A of figure 4-9 shows the proper method of stacking the required washers, and terminal lugs and of

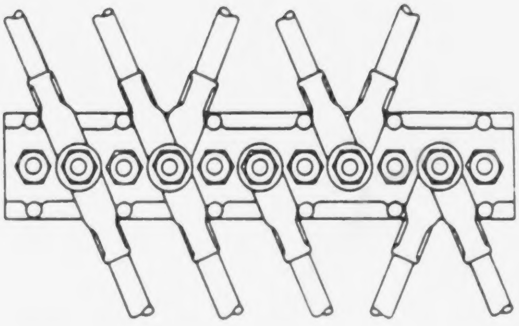

NOTE: ALL TERMINALS SHOULD BE PLACED SO THAT MOVEMENT WILL TIGHTEN NUT
C182-3381
0-10r

Figure 4-8. Terminal lug placement.

securing nuts when connecting two copper terminal lugs together on the same terminal board connection. Either a standard nonlocking nut or a self-locking nut may be used in conjunction with the lockwasher. However, the preferred method is to use an anchor nut or self-locking nut.

Part B of figure 4-9 shows the proper method of connecting aluminum terminal lugs on a terminal board. Notice that in this method a washer is used between the bottom terminal and the terminal stud nut. The washers that make physical contact with aluminum terminal lugs should be cadmium-plated. This prevents the dissimilar metals (the copper stud and the aluminum terminal lugs) from making contact. The dissimilar metals plus moisture will cause corrosion. This is known as the battery-effect form of corrosion.

Whenever it becomes necessary for you to join copper and aluminum terminal lugs together on the same stud, they should be separated by a cadmium-plated washer. The aluminum terminal lug should be placed on the bottom with a cadmium-plated washer beneath it. A washer is never used between two aluminum terminal lugs or two copper terminal lugs. Placing a washer in this position only increases the resistance of the connection. A minimum of three threads must be exposed, after terminal lug-stacking on the end studs, to provide adequate space between the cover and the terminal studs.

Splices. Splices, like terminals, are manufactured in both copper and aluminum. Only copper splices and terminals may be used on copper wire, and aluminum splices and terminals may be used on aluminum wire. The crimp-on splices are more widely used on aircraft than are the solder type because they can be applied in an aircraft with minimum time and effort. The crimped connections are made more rapidly, are cleaner, and are more uniform. Because of the pressures exerted and the materials used, the crimped connection, when properly made, has an electrical resistance that is less than that of an equivalent length of wire. A further refinement of the solderless splices is the insulated type. The barrel of the splice is inclosed in an insulation material. The insulation is compressed along with the terminal barrel when crimping, but it is not damaged in the process. This eliminates the necessity of taping or tying an insulating sleeve over the joint.

Each splice size can be used for more than one wire size. The splices are color-coded in the same way as are terminal lugs for wire sizes 26 thru 10. TO 1–1A–14, *Installation Practices Aircraft Electric and Electronic Wiring,* covers the details of splices, terminals, and connector plugs.

Connector Plugs. Connectors (cannon plugs) installed on aircraft join segments of electrical circuits and simplify maintenance by providing a means of quick removal and installation of electrical equipment. Connectors consist of two parts: a plug (with threaded coupling ring) and a receptacle assembly. The receptacle is usually the "fixed" part of the connector that attaches to a wall, bulkhead, or equipment case. The plug is the "removable" part of the connector. When the two parts are joined, electrical contact is made by pin-and-socket-type connections inside the connector. A key and keyway arrangement in the barrel of the plug and receptacle insure that the connector halves are not mismated. Standard connectors have the key and keyway located adjacent to the A pin or contact (each pin and contact is lettered).

When a key/keyway type of connector is put together, there should never be any need to force the two halves together. If the key is properly aligned with the keyway, a small amount of pressure should do the job. A key should never be filed off to facilitate assembly; there have been disastrous results when the pins were later inserted into the wrong sockets.

Connectors come in many sizes and types. The part number stamped on the barrel can be used to determine many things about the connector. These are type, class, size, insert arrangement, and insert position.

Many connectors use solderless crimp-type pins and sockets. These connectors require special insertion and extraction tools for the repair and replacement of the pins and sockets. It is beyond the scope of this CDC to go into the procedures used on these connectors. You should always refer to TO 1-1A-14 when you need information on a specific connector.

Exercises (066):

1. How would you stack copper and aluminum terminals on the same stud?

2. How are terminal lugs secured to terminal studs?

3. What method of splicing is most widely used?

4. What is used to insure proper mating of the connector plug and receptacle?

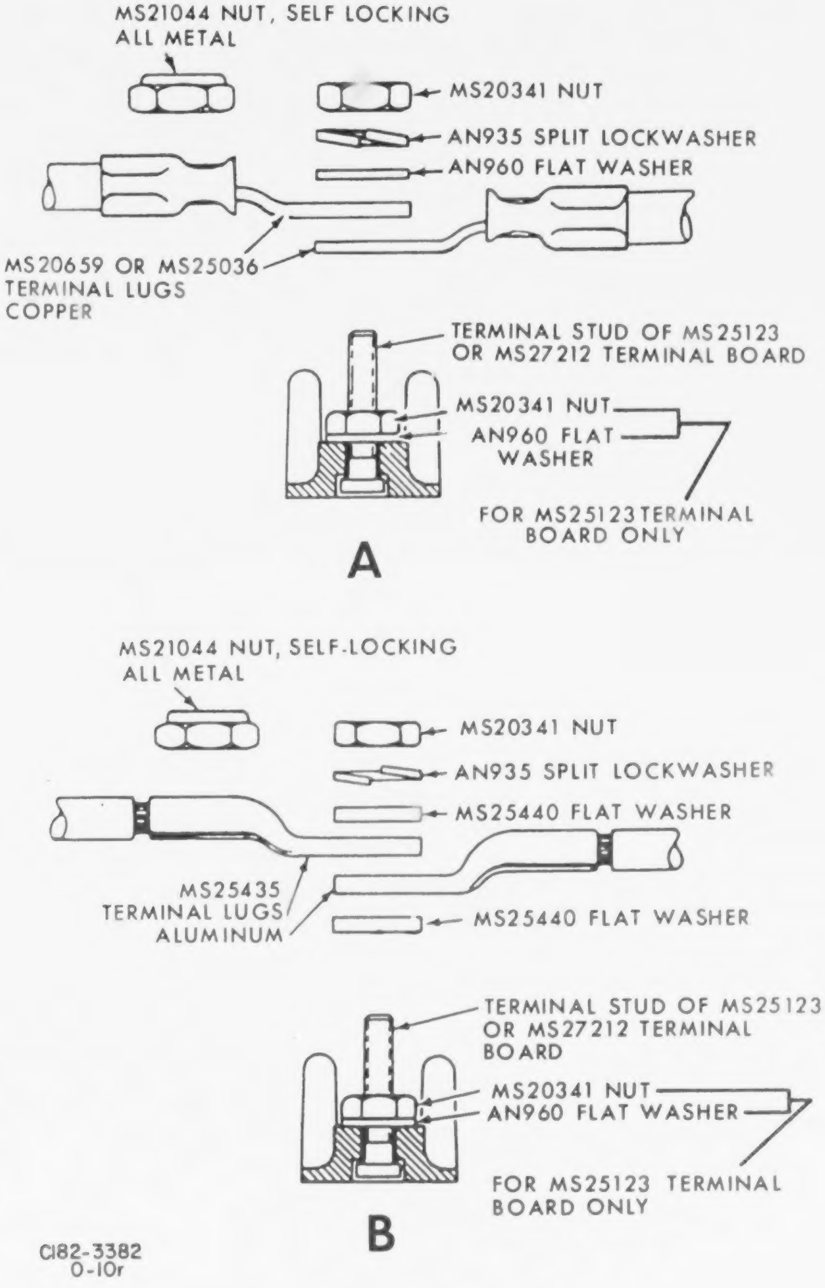

MS21044 NUT, SELF LOCKING
ALL METAL
MS20341 NUT
AN935 SPLIT LOCKWASHER
AN960 FLAT WASHER
MS20659 OR MS25036
TERMINAL LUGS
COPPER
TERMINAL STUD OF MS25123
OR MS27212 TERMINAL BOARD
MS20341 NUT
AN960 FLAT
WASHER
FOR MS25123 TERMINAL
BOARD ONLY
A
MS21044 NUT, SELF-LOCKING
ALL METAL
MS20341 NUT
AN935 SPLIT LOCKWASHER
MS25440 FLAT WASHER
MS25435
TERMINAL LUGS
ALUMINUM
MS25440 FLAT WASHER
TERMINAL STUD OF MS25123
OR MS27212 TERMINAL
BOARD
MS20341 NUT
AN960 FLAT WASHER
FOR MS25123 TERMINAL
BOARD ONLY
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Figure 4–9. Terminal lug stacking.

4-4. Aircraft Wiring and Tools

System components, regardless of their complexity, high reliability, or cost, are only as good as the wiring that interconnects them with the rest of the system. A 30-cent connector improperly installed can render a $30,000 system useless. Wiring installation or repair is a very important part of your job as an aircraft electrical systems specialist. This section deals with the types of wire and how it is used in aircraft systems. It also covers some of the tools you will use on the job.

067. Specify the most common-type wire used, how size is determined, and how wires are protected.

Electrical Wiring. Materials used for wire are silver, copper, gold, and aluminum. Silver is a better electrical conductor than copper, but copper is more widely used for economic reasons. The fact that copper is used as a conducting material to a greater extent than any other material is accounted for not only by its ability to conduct electrical current and its relatively low cost, but also by its physical characteristics in general. It has high-tensile strength, relative freedom from atmospheric corrosion, and is easy to solder.

Aluminum is the principal competitor of copper as an electrical conductor; you use it when minimum weight is a major consideration. Certain problems encountered with aluminum wire generally restrict its use to large-size wire and to positions such as power-feeder leads. Disadvantages must be considered when aluminum is being installed in an aircraft. Aluminum wire, for instance, is softer than copper wire, and continued bending of aluminum wire will cause "work hardening" of the metal, which makes it brittle. This causes strands of the wire to fail or break much sooner than strands of copper wire. Aluminum wire on an aircraft should be carefully inspected for nicked strands, as damaged strands will fail in service.

Another troublesome problem encountered when using aluminum wire is the presence of electrically resistant aluminum oxide, which you must either penetrate or remove to guarantee a satisfactory electrical connection. A compound is used to remove this film.

Wire size. Wire size is designated by a wire gage numbering system. The sizes most commonly used on aircraft vary from number 22, the smallest, to number 0000 (sometimes written 4/0), the largest. This system closely approximates the American wire gage (AWG) system, but it is improper to refer to aircraft wire as AWG.

The approximate wire size is determined by the smallest slot of the wire gage that the stranded wire will pass through easily (each slot has an associated number). Slots larger than those associated with number 1 are identified by fractions which indicate the wire diameters. A wire gage for rough approximations in the field, should be used only when complete wire tables are not available.

Wire insulation. Insulated wires used in aircraft consist of stranded aluminum or copper conductors, covered with a dielectric or insulating material. This insulation may consist of several materials. It provides thermal, abrasive, and moisture protection.

Wire specifications. Insulated wires are rated by the voltage the insulation can withstand, and by the wire's current-carrying ability. You can obtain the information you need by referring to the military specification of a specific wire. For example, MIL-W-5086 is a copper wire used for general-purpose wiring on most aircraft electrical systems. Specifications further identify it as a stranded tinned-copper conductor with insulation that is resistant to abrasion, moisture, and aircraft engine oils; also it is identified as partly resistant to flame and fungus. Temperature limitations, ohmic values per thousand feet, and the current-carrying capacity are also given in the military specifications for wire.

Wire replacement. For wire replacement, you should consult the aircraft's maintenance instructions manual, since it usually lists the wire used in a given aircraft. When the wire size cannot be obtained from this manual, you should use TO 1-1A-14 to help you select the correct size and type of wire needed. This publication can help you in make the proper decision while you consider the following factors:

a. Current drawn by the load.
b. Length of wire required.
c. Allowable voltage drop of the wire.
d. Maximum voltage applied.
e. Approximate temperature to which the wire is to be subjected.

Wires built to withstand extremely high temperatures are used in certain installations. Take particular note of these areas to insure that general-purpose wiring is not used for replacement of high-temperature wire.

Wire identification. All aircraft wiring is identified by a numbering system. New wiring to be installed in an aircraft must be properly marked before it is installed. Wires should be marked every 15 inches down the line, and 3 inches from each end or junction (except permanent splices). Wires less then 3 inches in length, or wires exposed at both ends, need not be marked.

Cutting wire. Large copper wire will be cut with a power circular saw with a special cable-cutting blade. Large copper wire may also be cut with a hacksaw providing the hacksaw has 20 or more teeth per inch. Small copper wire may be cut to length with diagonal cutting pliers.

Special cable shears with concave cutting edges may be used to cut small aluminum wire. Large aluminum wire should be cut with a power circular saw which has a cable-cutting blade. Aluminum wire should never be cut with tools that have reciprocating motion, such as hacksaws. Reciprocating cutting action "work hardens" aluminum wire.

Wire stripping. Before connectors, terminal lugs, splices, etc., can be installed on a wire, the insulation must be stripped from the connecting ends to expose the bare conductor. The amount of insulation you remove is determined by the connection that is to be made. Refer to TO 1-1A-14 for the proper length and procedures. Copper wire can be stripped in a number of different ways, depending upon size and insulation. The only authorized way to strip aluminum wire is with a knife. Even then, take extreme care not to nick the aluminum wire. Nicked or

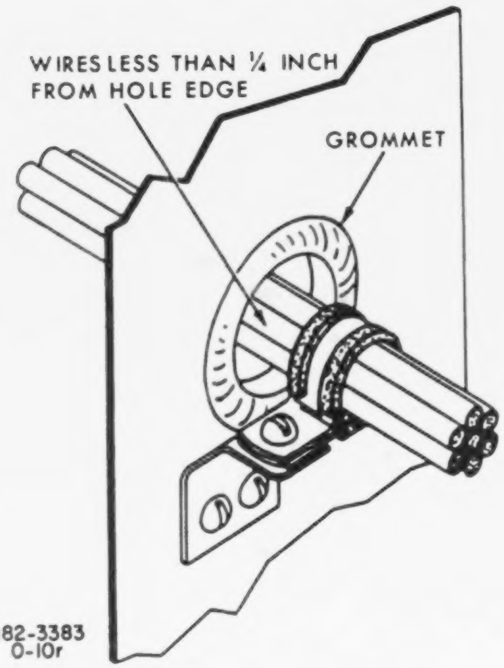


Figure 4-10. Routing wire bundles through bulkheads.

broken strands are not permitted on aluminum wire. On the other hand, the number of nicked or broken strands permitted on copper wire vary from 2 strands on number 10 wire to 12 strands on single 0 wire.

Wire installation. You must install and route aircraft wiring in such a manner that it is protected from undue wear or chafing. Chafing and abrasion of electrical wires is generally eliminated if you use military standard (MS) cable clamps. Figure 4-10 shows the proper method of supporting a wire bundle that comes closer than 1/4 inch to the structure when passing through a bulkhead. If the clearance is greater than 1/4 inch, you need not use the grommet.

Military standard cable clamps can also be utilized to provide a rigid separation (not for bundle support) when you route a wire bundle close to combustible fluid or oxygen lines. When this separation is less than 2 inches, enclose the wire bundle in a nylon sleeve for further protection. Whenever possible, wire should be routed away from resistors, exhaust stacks, heating ducts, etc. If you must run wires through hot areas, the wire should be insulated with high-temperature-resistance material, such as asbestos or fiberglass. Never use low-temperature wire in these areas.

Never route wire below a battery. Wiring installed in battery areas should be inspected frequently, and if any wiring is found to be discolored by the battery fumes, they should be replaced.

Avoid areas where the wires are subjected to damage from fluids. If wiring might be dampened or soaked in any location, enclose it in plastic tubing which extends beyond the wet area and tie it at each end. When wires and cables which are enclosed in tubing are pressed downward toward a connector, terminal block, etc., a trap or drip loop should be provided. The lowest point of the tubing should have a 1/8-inch drain hole, as shown in figure 4-11. This hole is punched in the tubing after the installation is complete, and the low point definitely established. However, the hole should not be punched in the tubing if the loop is in a wet area or is exposed to fumes detrimental to the insulation of wire.

Do not provide excess slack in wiring installation except for a drip loop and service requirements. Enough slack should be provided to meet the following needs:

a. Permit ease of maintenance.

b. Allow replacement of terminals at least twice, where practical.

c. Prevent mechanical strain on the wires, cables, cable junctions, and cable supports.

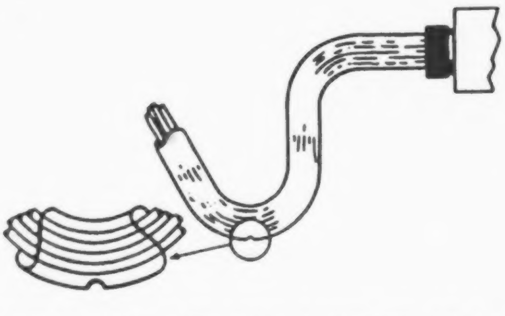
d. Permit free movement of shock- and vibration-mounted equipment.

f. Permit shifting of equipment in order to make possible aligning, servicing, turning, removing of dust covers, and changing of tubes while installed in an aircraft.

f. Eliminate sharp bends in order to prevent breakage and damage to wire insulation.

Wires and cables that attach to assemblies where movement occurs (such as hinges, rotating pieces, control wheels and columns, flight-control surfaces, and particularly control sticks) should be protected to prevent deterioration caused by movement of system components. This abrasive deterioration occurs when the wire or cable rub together or is twisted and bent excessively. Bundles must be installed so that they twist rather than bend across hinges.

Wiring in wheel wells or other open areas subject to excessive wind and flying objects should be protected by flexible tubing or installed in metal conduit. The wiring installed in these areas (except in the metal conduit) should be inspected frequently for damage.



DRAINAGE HOLE 1/8 INCH DIAMETER AT LOWEST POINT IN TUBING. MAKE THE HOLE AFTER INSTALLATION IS COMPLETE AND LOWEST POINT IS FIRMLY ESTABLISHED.

Figure 4-11. Drainage hole in low point of tubing.

Exercises (067):

1. Of what material is the most widely used aircraft wiring made?

2. What does a larger wire gage number indicate as concerns the size of the wire diameter?

3. How is insulated wire rated?

4. When should grommets and cable clamps be used?

5. In what situations should tubing be used, and what type of tubing is required in different areas?

068. Cite procedures and materials for tying and lacing wire bundles.

Tying and Lacing. You lace or tie wire groups and bundles for ease of installation, maintenance, safety, and inspection. By keeping all cables neatly secure in groups, the cable does not chafe against equipment or interfere with equipment operation.

Tying is the securing together of a group or bundle of wires with individual ties at regular intervals around the group or bundle. Tie all wire groups or bundles where supports are more than 12 inches apart and space the ties 12 inches apart or less. When ties are used to aid in making up and installing wire groups or bundles, use colored cord. This is called *temporary* ties and will be removed when the installation is complete. Cut temporary ties to avoid damage to the newly installed bundle. The use of scissors or diagonal pliers for cutting temporary ties is recommended.

Flat tape should be used wherever possible for lacing and tying. Round cord may be used but its use is not recommended, since cord has a tendency to cut into wire insulation. Cotton or linen cord or tape must be prewaxed to make it moisture- and fungus-resistant. Nylon can be of the waxed or unwaxed type. Fiber cord is usually not waxed.

Another method of securing wire bundles is the self-clinching cable straps. These are adjustable, lightweight, flat nylon straps with molded ribs on the inside surface to grip the wire. They may be used instead of individual cord ties for fast securing of bundles.

When installing the self-clinching straps on coaxial cable or bundles of coaxial cable, make sure the tension adjustment on the installing tool is set properly. It should exert just enough pressure to keep the cable from slipping. Because the straps can break, do not use them in areas that could cause the pieces to fall into movable parts. Avoid using molded nylon straps in areas where temperatures exceed 250°F (121°C).

Exercises (068):

1. What is the maximum allowable distance between ties on a wire bundle?

2. When are colored ties utilized?

3. Cite the advantage of flat tape over round cord.

069. Define the terms "bonding" and "grounding" and the considerations to make during both processes.

Bonding and Grounding. A bond is any fixed union which exists between two metallic objects and permits good electrical conductivity between them. Grounding is a term closely associated with bonding, but grounding refers to the electrical connection made from a conducting object to the primary structure. This ground provides a low resistance return path for current.

If repair or replacement of bonds or grounds becomes necessary, be sure to use the same type of hardware as that in the original connection. Do NOT make any changes in hardware. Using a different type of hardware could cause a high resistance to build up between dissimilar metals, and the bond or ground would be ineffective. Cushioned clamps should never be used in any bonding or grounding connection as the cushion acts as an insulating material and will not complete the path for current to flow.

Before any bonding or grounding connections are made, all surfaces in the connection area must be thoroughly cleaned to remove all paint, oil, grease, or dirt.

An ohmmeter reading of 0.1 ohm or less must be read across the bonding or grounding jumper before it is installed. After it is installed and a good mechanical connection is made, a test with a milliohmmeter must be made of the overall resistance between the cleaned area of the object and the structure.

Clouds may become highly charged, as is evidenced by lightning. An aircraft in flight may also become highly charged. If the aircraft is improperly bonded, all metal parts will not have the same degree of charge. A difference of potential will then exist between various metal surfaces. The neutralization of the charges flowing in paths of variable resistance, due to intermittent contact caused by vibration or the movement of the control surface, will produce electrical disturbances (noise) in the radio receiver. If the resistance between isolated metal surfaces is great enough, charges can accumulate until the potential difference becomes high enough to cause a spark. This creates radio interference and constitutes a fire hazard. If lightning strikes the aircraft, a good conducting path is necessary for the heavy current in order to minimize severe arcs and sparks that would damage the aircraft and possibly its occupants. Bonding does the following things:

a. Minimizes radio and radar interferences by equalizing static charges.

b. Eliminates a fire hazard by preventing static charges from accumulating between two isolated members which could create a spark.

c. Minimizes lightning damage to the aircraft and its occupants.

d. Provides the proper "ground" for proper functioning of the aircraft radio.

e. Provides a low-resistance return path for single-wire electrical systems.

Exercises (069):

1. When repair or replacement of bonds or grounds are made, what must be considered with regard to the hardware used?

2. A bond or ground jumper wire replacement should read no more than what ohmic value?

3. What is meant by the term "grounding?"

4. Tell what is meant by the term "bonding."

070. Describe compact wire bundles in terms of their use and effect on thermofit material.

Compact Wire Bundles. Compact wire bundles are being installed in newer aircraft to save weight and space and to provide better protection with less maintenance. Compact wire bundles are fabricated from hookup wire. This wire has thinner insulation and has poor abrasion resistant qualities. Therefore, a braided outer jacket over the wire bundles is required for abrasion protection. Solderless electrical connectors used on these harnesses are crimped, potted (a rubber-like coating), and then covered with a protective outer boot. The boot extends back from the connector shell, covers the potting compound, and overlaps the braid to form a strong moisture-proof seal (see fig. 4-12).

Wires inside the bundle are spiraled in groups. Each group is composed of wires that leave the bundle at the same point. The wire group that extends the greatest distance should be placed nearest the center. Individual wires, which branch out of the main bundle, are covered separately with shrink sleeving. A wire number is stamped on this sleeve, and the sleeve extends into the braid covering. When spare wires are provided, they extend 4 to 6 inches from the end of the boot and are terminated in thermofit end caps, as shown in figure 4-12. These spare wires are wire marked and secured to the bundle with lacing-tape ties.

The type of wire and the protection used for the fabrication of compact wire bundles have created situations that require special techniques for reworking the bundles. New crimping tools have been developed for installing special solderless connections. The thermofit materials are made from silicone rubber and require heating devices.

A special heat shrinking process is used on the thermofit materials in the construction and repair of compact wire bundles. Thermofit is a material with special qualities

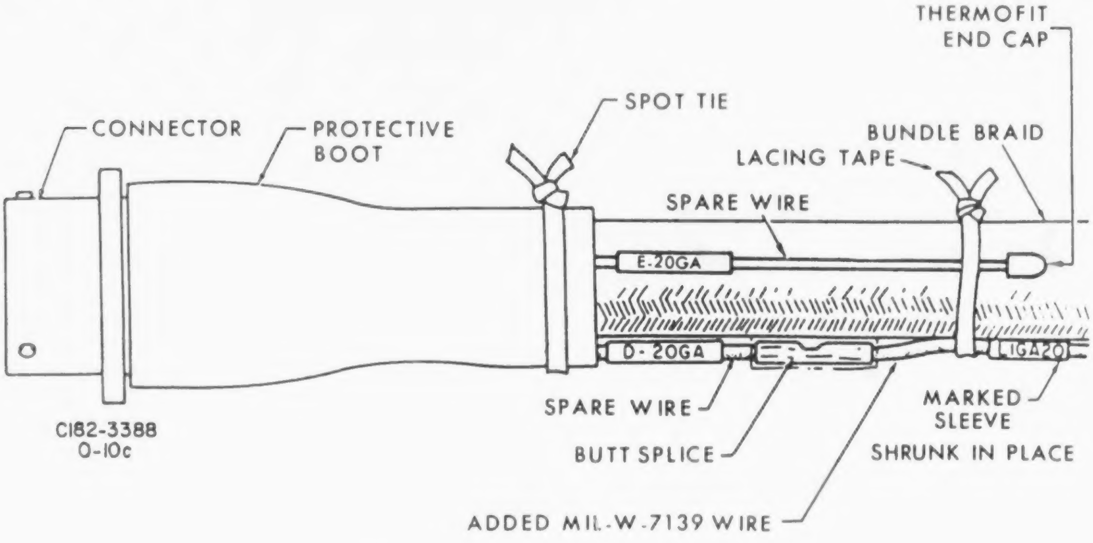


Figure 4-12. Protective boot on compact wire bundle.

which will shrink to at least half of its original diameter when heat is applied to it. Thermofit is used in the fabrication of boots, end caps, sleeving, and tubing. Special adapters and reflectors make it possible to shrink most of the thermofit devices with the same gun. This heat gun must be used with extreme care because of its high operating temperature. Never use the hot-air gun on fueled aircraft, its exposed heating element could cause a fire or an explosion. If the aircraft is purged, this tool can be used.

Exercises (070):

1. How are thermofit materials made to fit over wire bundles?

2. What type of material is used in the fabrication of boots, end caps, sleeving, and tubing?

3. How much will thermofit shrink when heated with the heat-shrinking tool?

4. What tool is used with the compact wire bundle and thermofit material?

071. Cite the special tools used by the aircraft electrical systems specialist to mark, crimp, and strip electrical wire.

Tools. Tools of any kind are only as good as the individual using them. Naturally, tools wear out, but this can be corrected. You should know each of your tools, what it was designed for, and most of all, how to use it.

Wire-marking Machine. This is one tool that may sit on the shelf for 6 months before you need it; but when you do need it, there is no substitute. A typical hand-operated, wire-marking machine uses an electrical heating element which applies heat to the type holder and the type. A roll of marking foil is positioned between the type and the wire to be marked. The wire is held in place by a wire guide, and a lever on the machine brings the type in contact with the foil and wire. Pressure is then applied to the foil and it transfers marking material from the foil to the wire. The complete operating procedures can be found in TO 1–1A–14.

Crimping Tools. The crimping tool, or "crimpers" as it is often called, has taken the place of the soldering iron in many places. This tool is easy to use and does not require any electrical power. If you use water pumps or diagonal pliers for terminal crimping jobs, then you will have to replace your goofs, so we need to discuss using the right tool for crimping.

These tools usually make a flat-type crimp, but some crimpers make an indent-type crimp. The indent-type crimping tool should be used only on the noninsulated terminals or splices. If the indent crimping tool is used on a preinsulated terminal or splice, it will damage the insulation and cause a short.

The flat-type crimping tool is used with the preinsulated terminals and splices. These crimpers will crimp a variety of terminal sizes. To choose the right one, check the color code or numerical coding on the tool. The color or numerical code identifies the size of the splice or terminal which the tool will crimp. Before any terminals or splices can be crimped, the wire has to be properly stripped of its insulation. To do this, you need a wire stripper.

Wire Stripper. This device removes the insulation from an electrical wire. The wire strippers that you will encounter most often on the flight line or shop will be either a hand stripper or a common jackknife. Figure 4-13 illustrates these wire strippers. The main thing to remember in using a wire stripper is not to damage the wire strands. A few hours of experience will make you proficient in the task of stripping wire.

The electrical handtools we have discussed are not your complete issue of tools. You have others, and you need to know what each one does. If you keep them clean, keep them in good mechanical condition, and use them for the job for which they were designed, they will make your job easier.

Exercises (071):

1. How is the wire number transferred from the hand-operated, wire-marking machine to wire?

2. What tool has taken the place of the soldering iron in many cases?

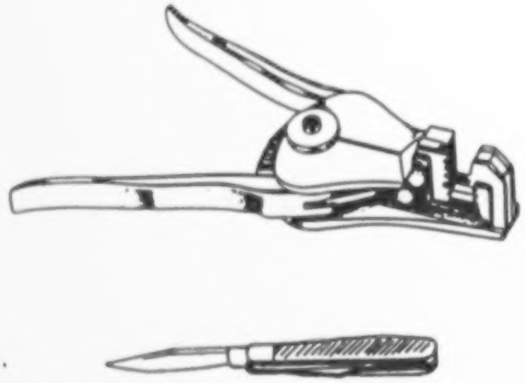


Figure 4-13. Wire strippers.

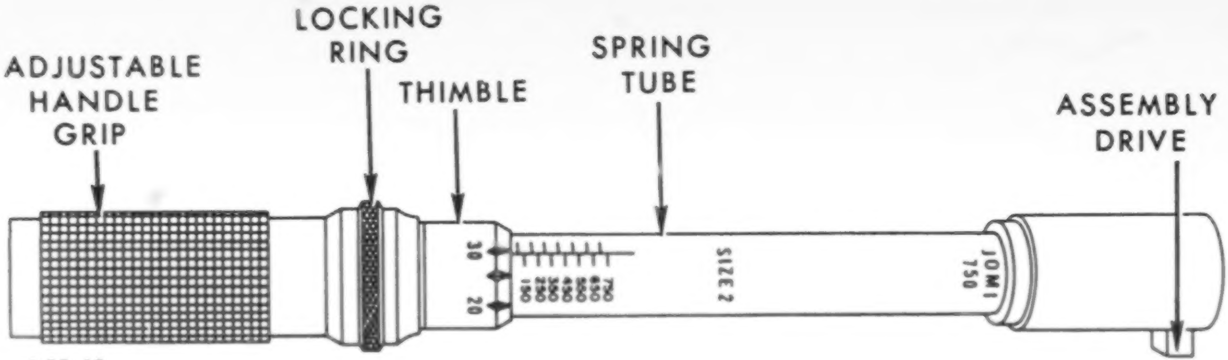


Figure 4-14. Breakaway-type torque wrench.

3. What two tools are commonly used to remove insulation from wires?

072. Specify the proper selection, use, and care of torque wrenches.

Torque Wrenches. Torque wrenches are used to measure torque (twisting force) applied to bolts, nuts, clamps, hoses, and tubing when they are being installed. Some of these wrenches are designed to measure torque in inch-pounds and foot-pounds. The most common type of torque wrench used in the Air Force is the "breakaway" type, sometimes referred to as the automatic-release torque wrench.

The breakaway torque wrench has a square drive, shaft scale, vernier scale, grip or handle, and grip lock. (See fig. 4-14.) The square drive may be 1/4, 3/8, 1/2, or 3/4 inch. The size you choose depends on the job. For instance, a torque value of under 100 inch-pounds requires a 1/4-inch square drive.

Breakaway torque wrenches are adjustable, and a desired torque value can be set (within the limits of the torque wrench) by turning the handle or grip to settings on the micrometer-type scale. The micrometer-type scale consists of the shaft scale and vernier scale. To increase the torque setting of the wrench, turn the handle or grip clockwise. To reduce the torque setting, turn the handle (grip) counterclockwise. Turning the handle changes the scale reading of the micrometer-type scale while, at the same time, reducing or increasing tension on the spring inside the handle. The desired torque setting should always be approached from the lower end of the micrometer-type scale.

The breakaway torque wrench has a locking device to insure that the desired torque value does not change when the wrench is used. Some locking rings are turned to engage the lock in the handle. In other wrenches, locking is done by sliding the lockring along the handle to engage a pawl or slot in the shaft. In either case, the handle is prevented from turning when the wrench is in use. The lock must be "unlocked" before the handle can be turned.

Torque wrenches issued from base supply to shops or toolcribs for use in the maintenance of aircraft, and other critical equipment must be checked and calibrated (if necessary) upon issue. After that, they must be checked at least once every 2 months (60 days). The 60-calendar-day period is to be calculated from the date of the last verification. Verification is a checking operation to determine accuracy, or inaccuracy, of a torque wrench using a tester. Calibration is the actual adjustment necessary to bring the torque wrench within acceptable tolerance. Thus, a torque wrench verified on 15 November 1982 is due for reverification on 15 January 1983. At the time of verification, color-coded, dated tape is fastened to the torque wrench around the spring tube. The color and the date of the tape indicate when the torque wrench is due for verification.

If a torque wrench is dropped or otherwise abused, it must be verified accurate and, if necessary, calibrated prior to further use. Torque wrenches are precision-measuring instruments and should be handled and treated like precision instruments. After using these wrenches, you should turn the grip counterclockwise to its lowest usable setting. This action removes the tension on the spring in the handle. The accuracy of the spring tension determines the accuracy of the wrench. After setting the torque wrench at its lowest setting, it should be stored in its own storage container.

Following are some of the precautions to observe concerning torque wrenches:

- Do not use an extension on the grip end of the handle.
- Do not use a torque wrench to break loose previously tightened bolts.
- Do not use a torque wrench to apply a greater amount of torque than the rated capacity of the wrench.
- Do not attempt to change setting when the handle is in a locked position.

- Do ot place an extension on the square drive to increase the length of the torque wrench.
- Do not use a torque wrench that has been dropped or abused, until it has been reverified as accurate.

EXCEPTION: In some cases, you cannot reach the item to be torqued and have to use an extension. An extension will change the torque applied because of the leverage advantage. If an extension is used, you must mathematically calculate the torque setting. Use the formula given in the appropriate TO for this calibration.

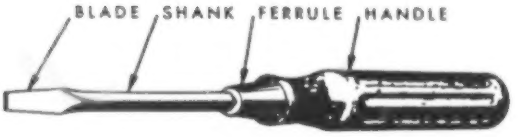
Exercises (072):

1. What type of torque wrench is used to torque a clamp to 25 inch-pounds?

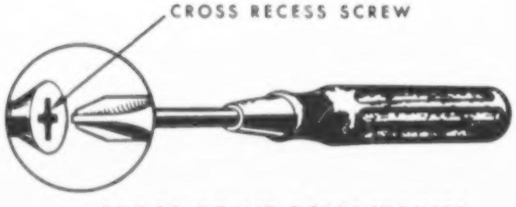
2. How do you reduce the torque setting on a torque wrench?

3. How often must torque wrenches be verified?

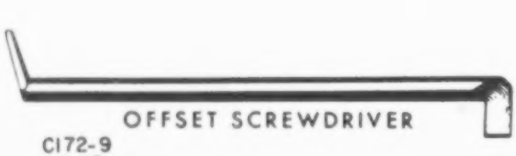
4. After using a torque wrench, at what setting should you store it?



STANDARD SCREWDRIVER



CROSS-POINT SCREWDRIVER



OFFSET SCREWDRIVER

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Figure 4-15. Common types of screwdrivers.

073. Describe screwdrivers in terms of their use.

Screwdrivers. Screwdrivers were designed for one purpose—to tighten or loosen screws. However, some people use them incorrectly as chisels, punches, putty knives, tire tools, wrecking bars, ignition or battery testers, can openers, ice picks, etc. Now, let us discuss the types and sizes of screwdrivers available to you.

A screwdriver has three main parts: the handle, the shank, and the blade, as shown in figure 4-15. Also shown is the ferrule used to secure the shank to the handle. Screwdrivers are sized and identified by the length of the shank. The handle is usually made of wood or plastic and is designed as a grip. The thin steel shank can withstand considerable twisting, but it is likely to bend or crack if it is used as a pry or pinch bar. The tip of the blade is hardened to keep it from wearing, and the harder it is the more easily it will break if much strain is applied. If the shank of a screwdriver is bent, it is usually difficult to straighten, and you will have trouble keeping the screwdriver in the center of the screw slot. The most common types of screwdrivers are the standard (flat-blade), offset, and cross-point. Figure 4-15 shows all three types.

Standard. The standard (flat-blade) screwdriver is available in many sizes and is the most frequently used of screwdrivers. Too much emphasis cannot be placed on selecting the correct screwdriver size. The screwdriver must be large enough for the job, and the blade should fit snugly into the screw slot. A good fit prevents the screw slot from becoming burred or the blade from being damaged. It also reduces the force needed to keep the blade in the slot. If a screwdriver does not fit completely into the slot, the screwdriver is likely to slip and could damage the material around the screw. If the blade on a flat-tip screwdriver isn't broken too badly, it can be ground on an emery wheel and made serviceable again. The tip of the blade should be ground to make the end square and flat and the sides practically parallel. The blade sides should taper in slightly and gradually taper out to the shank body. If you grind the screwdriver tip on the emery wheel, use a light pressure and do not overheat the metal because overheating removes the temper. Remove as little metal as possible so that you do not grind beyond the hardened area of the blade tip.

Offset. The offset screwdriver is a handy tool for use in tight places. One blade is forged in line with the handle or shank, and the other end is at right angles to the handle, as shown in figure 4-15. This screwdriver is used when there isn't enough room to use a standard screwdriver. Offset screwdrivers are also made with cross-point blade tips, and come in various sizes.

Cross-point. Cross-point screwdrivers are made with specially shaped blades or bites that fit cross-recessed screws, as shown in figure 4-15. This type of screwhead checks the tendency of the screwdriver tip to slip out of the recess and damage the surface of the work. Cross-point screwdrivers come in a variety of sizes. Take care to use the correct size for the screw you want to loosen or tighten. It is very easy to burr a crossed-recessed screw, and render it impossible to loosen.

Cross-recessed screws take a worse beating than standard screws, usually because the mechanic is too lazy to get the right screwdriver. Two types of cross-point screwdrivers commonly in use in the Air Force are the Phillips and the Reed and Prince. These are manufacturers' names, but they have been accepted for identifying a certain shape of tip. The Phillips and the Reed and Prince screwdrivers are often used mistakenly, simply because they resemble each other. They are not interchangeable because their tips are ground differently. The Reed and Prince tip is more pointed than the Phillips. Many mechanics seem to forget that there is a proper screwdriver for every job. Too often small screws are driven with a giant screwdriver, and the result is a scored slot.

Do not hammer or pound on a screwdriver handle. There are certain instances when you may have to tap on the handle. You may have to force the blade into a paint-filled screw slot, or to loosen a screw that won't budge. Tap on the handle of a screwdriver only if its shank extends through the handle. A screwdriver that does not have its shank extending through its wooden handle has the point "pinned" to the shank, usually through the ferrule. The ferrule is the metal sleeve on the wooden handle where the shank enters. If you attempt to use a hammer on a screwdriver of this type, you may split the handle and ruin the screwdriver.

Some screws are very difficult to remove, even when you tap on the handle of a screwdriver. In a situation like this, select a heavy-duty screwdriver with a square shank and a tip that fits the screw slot snugly. Apply a small wrench to the shank near the blade and use it as a lever for additional torque. You can then usually remove the screw easily. However, make sure that the screwdriver tip is fully and squarely seated in the slot before you apply any pressure. If you don't do this, you will force the tip from the slot and ruin the screwhead, making it extremely difficult to remove the screw.

Exercises (073):

1. How do you know whether you are using the right size screwdriver?

2. What precautions should be taken when using an emery wheel to reshape a standard common screwdriver?

3. What type of screwdriver should you use if there is not enough room to use a standard screwdriver?

4. What type of screwdriver is used for cross-recessed screws?

074. Match the various uses of pliers with specific types.

Pliers. Pliers rank close to screwdrivers as being the most misused handtool. Few tools can ruin more work than a pair of pliers. You have probably seen pliers used for everything from a pry bar to a pipe wrench. Pliers are designed to serve only a few purposes: to hold or grip small material, to cut small soft wire, or to bend light metal or wire into a desired shape. Pliers should never be used in place of a wrench to tighten or loosen nuts or bolts, especially on battery cable terminals. One who does so indicates a lack of understanding of the tool. Think of pliers as a holding tool, never as a tightening tool. There are many types of pliers, some of these are shown in figure 4-16.

Combination slip joint. One of the most commonly used pliers is the combination slip joint. These are sometimes called common pliers. Combination slip joint pliers come in 5-, 6-, 8-, and 10-inch sizes (the length of the handle determines the size). Some are made with a side-cutter arrangement. The slip joint allows the jaws to open wider at the hinges for gripping larger material. These pliers are used principally for holding or bending flat or round stock.

Diagonal cutting. Diagonal-cutting pliers (dike) are used for clipping cotter pins, pulling cotter pins, for spreading split ends of cotter pins, and for cutting soft wire. These pliers are sturdy but are not designed to cut bolts, rivets, or hard steel; neither are they designed to serve as tin snips. When you cut material with your "dikes," use the back (throat) of the jaws—not the point. Using the point in cutting may spring the jaws. Once the jaws are sprung, it is difficult, if not impossible, to cut fine wire with them.

Multiple slip joint. The multiple slip joint (water pump) pliers, shown in figure 4-16, are similar to the standard combination slip-joint pliers except that the jaws are offset. In comparison with combination pliers of equal length, more leverage can be applied to the jaws of the water-pump pliers. Water-pump pliers were originally designed for tightening water pump packing glands, but have since become a general-purpose tool. Unlike combination pliers, water pump pliers have five, instead of two, adjustments to the jaws. This feature make them a handy tool for gripping odd-shaped objects and hard-to-reach fittings when no other tool is available. However, do not use these pliers instead of a wrench.

Vise grip. As shown in figure 4-16, vise-grip pliers have a locking device on the movable jaw. The jaws are adjustable to openings of various sizes and automatically lock in position when the handles are closed. This tool is used primarily to hold parts securely while you are working on them. Since they lock in place, they free one of your hands.

Longnose. These pliers may have a round, flat, or duckbill tip. They will help you in many tight spots. Longnose pliers come in varying lengths. They are very

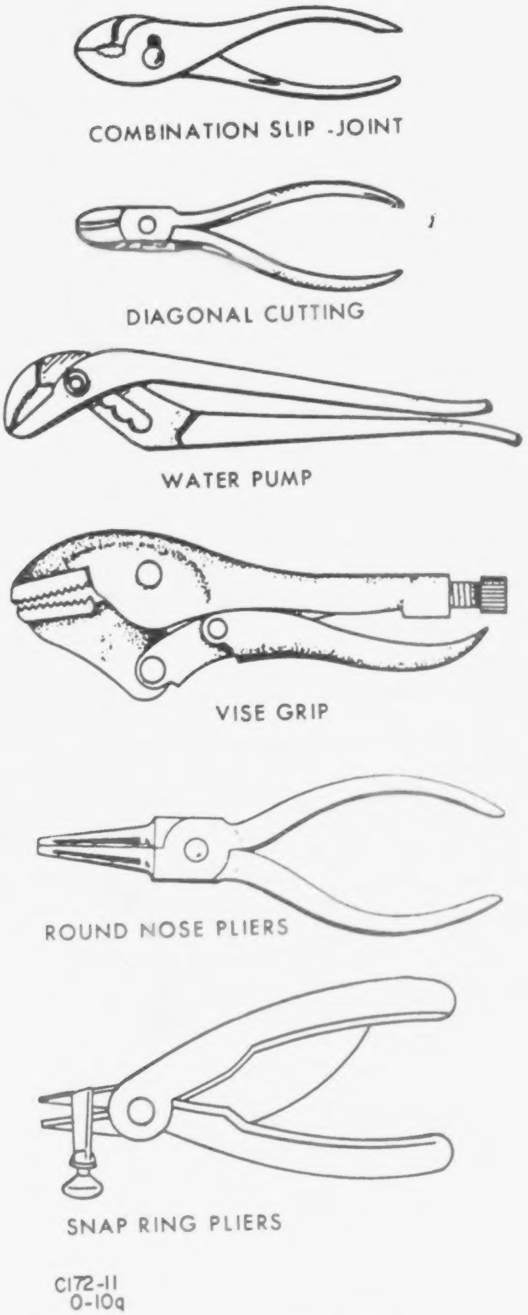

Figure 4-16. Commonly used pliers.

good for holding objects in confined places and for making delicate adjustments. The roundnose pliers are used to crimp or bend thin metal and to form loops in wire. Some of these have side cutters also.

Snapring. These pliers come in several different sizes—both inside and outside types. Specifically, they are designed either to spread snaprings or to clamp them together.

Pliers, like other tools, should be kept clean. Clean them occasionally with an approved cleaning solvent to wash off the dirt and grit. Also, give the joint pin an occasional drop of oil.

Exercises (074):

1. Match the correct action in column B with the jobs in column A.

Column A	*Column B*
____ (1) Gripping odd-shaped objects.	a. Do not use pliers; use another tool.
____ (2) Cutting soft wire.	b. Use adjustable water-pump pliers.
____ (3) Loosening nuts.	c. Use vise-grip pliers.
____ (4) Making delicate adjustments.	d. Use diagonal-cutting pliers.
____ (5) Holding parts securely while you are working on them.	e. Use longnose pliers.
____ (6) Clipping cotter pins.	
____ (7) Forming loops in wire.	
____ (8) Tighting bolts.	
____ (9) Replacing cotter pins.	

075. Explain the proper use of various wrenches.

Wrenchs. A good mechanic does not use pliers on hardened surfaces because this would dull the teeth of the pliers and cause them to lose their grip. Neither does a good mechanic use pliers to loosen or tighten nuts because this would round off the corners of the nuts.

Wrenches are tools designed for exerting a twisting strain, as in turning nuts or bolts. Most nuts and boltheads have six sides. A wrench is designed to fit the sides or flats of the nuts or heads. In using a wrench, you should always pull—never push. Pushing on a wrench is dangerous. If you push on a wrench to loosen or tighten a nut and the nut suddenly breaks loose, you will invariably strike your knuckles on some part of the unit on which you are working. If you must push, use the base or palm of your hand and hold your hand open; this hand position may save your knuckles from cuts and bruises.

The wrenches you will be using are probably made of chromium-vanadium steel. It is almost impossible to spring or break any of these wrenches if you use them properly. The most common types of wrenches you will use are the adjustable-jaw, the open-end, the box-end, and the socket.

Adjustable-jaw wrenches. The adjustable-jaw wrench, shown in figure 4-17, has a movable or adjustable jaw. The length of the handle determines the size of the wrench. Thus, a 6-inch adjustable wrench has a 6-inch handle, although its jaws open only to 3/4 inch. Adjustable wrenchs with longer handles have larger jaw openings.

The adjustable wrench is not intended to take the place of open-end, box-end, end, or socket wrenches. Use it only on an odd-size nut or bolthead that none of your other wrenches will fit properly.

Adjustable wrenches will not stand excessive strain, especially at the wide-open position. If you need to exert force on an adjustable wrench to "break loose" a tight nut, or to "snug down" a nut you are tightening, there are two

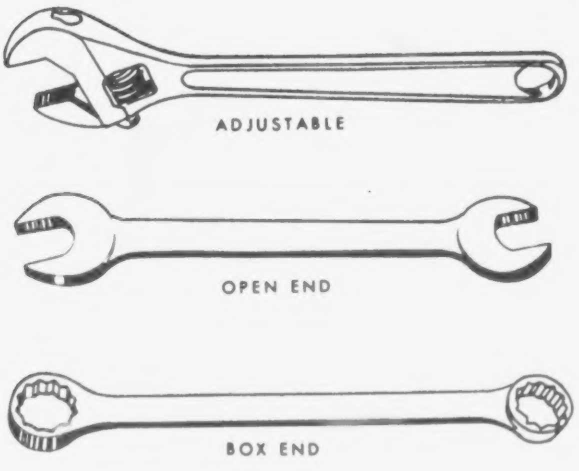

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Figure 4-17. Types of wrenches.

important points to remember. First, always place the wrench on the nuts so that the pulling force is applied to the stationary jaw. Second, after placing the wrench on the nut, tighten the wrench so the jaws fit the nut snugly. If you do not observe these two points, you are likely to spring or break the wrench on a hard pull.

Under no circumstances should you ever hammer on the handle of an adjustable wrench to loosen or tighten a nut. Also, you should not use an extension on the handle to get more leverage.

Open-end wrenches. Wrenches with an opening in each end, shown in figure 4-17, are called open-end wrenches. The size of the openings between the jaws determines the size of the wrench. The measurements refer to the distance between the jaws of the wrench, or across the flat of the nut or bolthead; they do not refer to the diameter of the bolt. If you measure the opening of your wrenches, you will find that they measure from 0.005 to 0.015 inch larger then the sizes marked on them. This small difference makes it easier to slip the wrench on and off boltheads and nuts.

The smaller the openings in the wrench, the shorter its overall length. This proportions the lever advantage of the wrench to the size of the nut or bolt. For a given amount of pull on a wrench, a shorter length produces less twisting or torque, and reduces the possiblity of stripping the threads.

The heads and openings of open-end wrenches are at an angle to the handle. Most are designed with a 15° offset, while some are designed with as much as 90° offset for special purposes. Wrenches with such special offsets permit working in close quarters. Turning the wrench over after each stroke reverses the angle of the head. The 15° angle of the jaw, plus the turning over of the wrench, enables you to continue turning a hexagonal nut, even when the swing of the wrench is limited.

Box-end wrenches. One of the features of the box-end wrench, shown in figure 4-17, is that it can be used in close quarters. These wrenchs are called box-end wrenches because they completely box (or surround) the nut or bolthead; thus, they aren't likely to slip. The wrench has 12 notches (or points) arranged in a circle. A 12-point wrench can be used to loosen or tighten a nut where the minimum handle travel is 30°. These wrenches are ideal on exposed nuts where they can be turned or spun in a complete circle. Another advantage of these wrenches is that there is little or no danger of their slipping off a nut if they are placed properly. The disadvantage of using these wrenches as compared to open-end wrenches is that they are slower. After each partial turn, a box-end wrench must be lifted from the nut and repositioned for another turn. A box-end wrench can be used to good advantage to finish securing nuts that have been tightened with an open-end wrench.

Socket wrenches. Because different handles can be used, the socket wrench is usually the strongest, safest, and fastest wrench in the toolkit. As shown in figure 4-18, there are many varieties of drives and adapters, such as extensions and universals which permit the use of sockets in close quarters. The handle choices are the speed handle, the hinge handle, the sliding T-bar handle, and the ratchet handle.

Handles and extensions used on sockets are made in many different drive sizes to fit specific types of work. The most common sizes used are 1/4-, 3/8-, 1/2-, and 3/4-inch drives. The drive size refers to the size of the end that fits in the socket. The 1/4-inch is used for very light work and the 3/4-inch for very heavy work. In using these wrenches, you first loosen the nut of capscrew with the hinge handle, shown in figure 4-18. Then you use the speed handle. If close quarters prevents the use of the speed handle, the ratchet handle is used. Don't use the ratchet handle on heavy work, because it is not made for work requiring great strain. The last choice would be the sliding T-bar handle that is used in close or confined places. Various lengths of extension bars, figure 4-18, are available. These are used with sockets to reach fasteners located in deep recesses. The extensions provide knuckle clearances over projecting objects. The deep socket, shown in figure 4-18, usually has thinner walls than the standard socket; both are available in a variety of sizes. The deep socket is used to reach recessed spark plugs, nuts, and studs on cylinders and other hard-to-get-to places.

A universal joint, shown in figure 4-18, can be used with many combinations of handles, extensions, and sockets to reach nuts and bolts at various angles. The universal joint is therefore very useful. With experience, you can work out any number of combinations for hard-to-reach places.

Allen wrenches. Another type of wrench you may sometimes have occasion to use is the Allen wrench. This wrench is a six-sided, L-shaped rod and is designed to fit into the recessed head of a setscrew or capscrew. Either end of one of these wrenches will fit into the recess, making it useful where either a long or short reach is desired.

Exercises (075):

1. For what reason should you pull, rather than push, with a wrench?

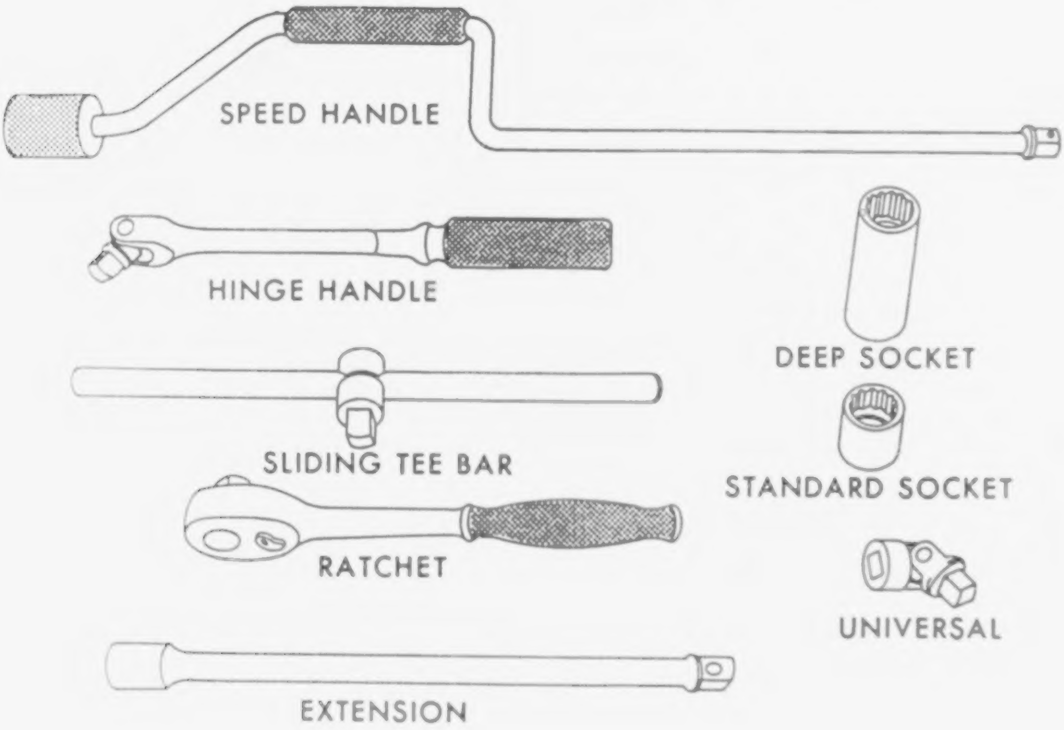

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Figure 4–18. Socket-wrench handles and attachments.

2. Which type of wrench should you use for loosening and tightening odd-sized nuts and bolts?

3. Indicate whether the following uses of wrenches are proper by writing "yes" or "no" in the spaces provided.

____ a. Using an extension on the handle of an adjustable-jaw wrench in order to get more leverage.
____ b. Turning a box-end wrench in a complete circle to loosen an exposed nut.
____ c. Using an open-end wrench considerably larger than the bolthead to be turned.
____ d. Using a ratchet handle and socket for heavy work.
____ e. Applying the pulling force to the stationary jaw of the adjustable wrench.
____ f. Using an extension and socket to reach recessed nuts.
____ g. Using the adjustable-jaw wrench as your all-purpose wrench.

4-5. Soldering

Soldering is the process of joining two or more metals together at a temperature lower than the melting points of the metals. Generally speaking, you use either a soldering iron or a soldering gun. For successful and effective soldering, the soldering-iron tip must be tinned. After a day of use, remove the tip from the iron and clean out the black scale from inside the iron. The tip should be cleaned with fine steel wool as necessary. If you are issued an iron, you will probably be given several soldering-iron tips. These come in assorted sizes and shapes. You must determine which is the correct tip for the job. When you solder a connector plug, use a tip that will give you sufficient heat without burning the insulation from adjacent wires. Again, keep it clean and tinned. DO NOT lay a HOT IRON where someone can get burned.

076. Cite differences between solders.

Solders. Solders fall into two general categories—hard and soft. The main difference between the two is in the composition of the fusing metal used. Hard solders are usually made of alloys containing silver. These solders are referred to as "silver solders." In contrast, soft solders are alloys of tin and lead. One of the low-melting temperature solders is composed of 60 parts tin and 40 parts lead. Such solder has a melting temperature of approximately 340°F. It is available in both bar and wire form.

Most of the solder you will use in repairing circuits is classified as soft solder. It comes in wire form, and the wire is hollow and filled with rosin flux. Why is the rosin flux essential? Because it prevents oxygen in the air from combining with the metals that are to be soldered. Without flux, the heating of the metal causes a film of oxide to form which then prevents solder from fusing with the metal. Rosin-core solder is recommended for all electrical soldering. Acid-core solder also acts as a flux, in that it cleans and removes oxides at the time it is being applied. We NEVER use acid-core solder for electrical or electronic circuits. Over a period of time, the acid will corrode the wire and destroy the connection. The corrosive and galvanic effect of acid-core solder also produces "noise" voltage in electronic circuitry. When these "noise" voltages are quite prominent, electronic equipment becomes faulty and sometimes even inoperative.

The electrical conductivity of solder which contains alloys of tin and lead is much lower than that of copper. For this reason, make certain that every joint is mechanically secure. This means you must have the conductors in close contact with each other before the joint is soldered. Otherwise, solder will flow between the conductors, thus setting up a resistance between them. Such junctions, called high-resistance solder connections, are a mark of inexperienced or sloppy workmanship.

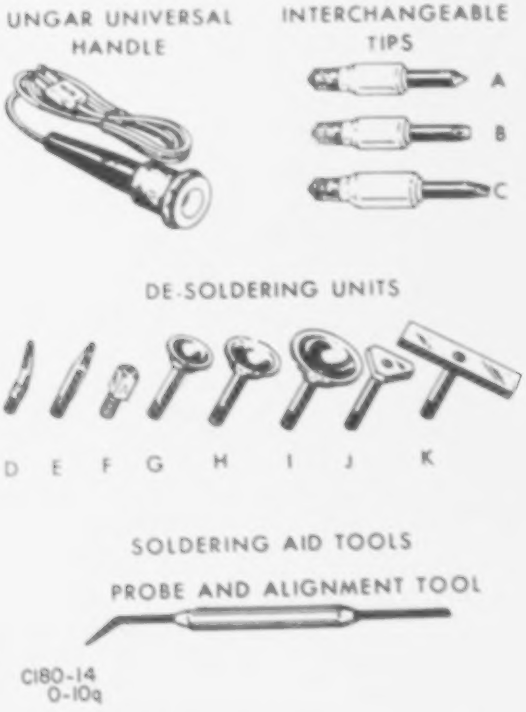

Figure 4-19. Recommended special tools and aids.

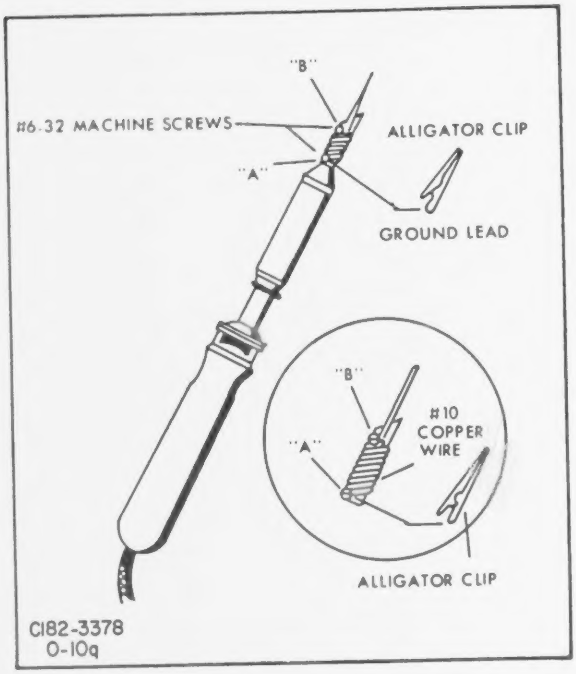

Figure 4-20. Improvised low-wattage soldering iron.

Numerous types and sizes of soldering irons are available. Using the correct iron in the right way is essential, if you are to make good, dependable connections.

Exercises (076):

1. a. Name the categories of solder.

   b. State the differences between them in composition.

2. Describe the solder most commonly used on electrical circuits.

3. What will happen to a circuit if acid-core solder is used?

077. State how to select and maintain soldering equipment.

Selecting a Soldering Gun or Iron. Many types and sizes of soldering irons and pistol-grip guns are available. The induction-type soldring gun is very useful, but you must consider several precautions concerning its use. One of its main advantages is the ability to rapidly provide sufficient heat for soldering normal-sized electrical circuit connections. You must not allow the gun to remain hot for extended periods. The induction coil becomes overheated very rapidly, and the gun may be damaged. (When you anticipate the need for a considerable amount of soldering, select an iron in preference to a gun.) DO NOT alter the shape of the gun's tip in any way. The two halves of the tip element are manufactured with a specific separation. Changing the distance between the elements will invariably result in poor heating. If the heating element should accidentally become bent, replace it. This insures proper heating and good solder connections. Before using a soldering gun, be sure the tip nuts are securely tightened. NEVER replace the tip with power applied to the gun. Since the tip heats rapidly, that funny smell may be your fingers burning.

Often you will have to perform lengthy repair work on soldered connections. The best tool for extended work is the soldering iron. We have the high-wattage iron (usually 100 watts and higher) for general use, and low-wattage irons (under 100 watts) for soldering small, closely situated components The pencil-type soldering irons have resistive heating elements and are well suited for use on printed circuits. To avoid overheating and damaging transistors and other semiconductor devices, a small low-wattage (50 watts or below) soldering iron with a narrow point or wedge must be used. An iron with interchangeable tips, as shown in figure 4-19, is recommended; but a high-wattage iron can be converted for emergency use.

To make the conversion, closely wrap any number of turns of clean No. 10 copper wire around a thoroughly clean soldering-iron tip, extending the other end of this wire 1 inch beyond the original soldering-iron tips, as shown in figure 4-20. To provide a tight connection and prevent possible twisting of the tip, secure the No. 10 wire coil end at points A and B with No. 6–32 machine screws. Attach a flexible ground wire to point A, figure 4-20. Provide the other end of this wire with an alligator clip to permit convenient grounding of the soldering iron.

Tip Dressing and Cleaning. Before attempting to use a soldering iron or gun, make sure the tip is properly prepared. The tip must be clean and free of pits. If pitted, the tip may be reshaped by filing with a flat, fine, single-cut file. To prevent oxidation of the newly dressed tip, it should be immediately tinned (coated with solder). A clean, shiny tip will provide the best possible heat conduction, thus making the soldering process quick and easy.

During the course of normal use, the tip will become encrusted with residue from the solder flux or paste. This hard, black, crystalline residue will cause poor heat conduction and, possibly, damaged terminals. The best and easiest method of cleaning is known as thermal-shock cleaning. When soldering, keep a moist sponge or cloth handy. As the tip becomes dirty, simply wipe it across the sponge. The sudden application of the sponge with its cool moisture to the tip breaks up the crust and wipes it away. The tip will cool very slightly, but it will rapidly reheat. Thermal-shock cleaning will result in a bright, shiny tip.

Exercises (077):

1. a. What type of soldering unit would you select if you had 4 or 5 small wires to connect, but you must mechanically fasten each wire just before soldering it?

   b. Explain why.

2. a. What type of soldering unit would you select if you were to work on printed circuits?

   b. Explain why.

3. How do you remove pits from a soldering iron's tip?

4. After the tip is properly shaped, what must be done immediately and quickly?

5. What type of soldering tip cleaning is recommended during normal use?

6. What type of solder tip-cleaning is recommended during normal use?

078. Explain how to solder electrical connections in terms of procedures and precautions.

Soldering Procedures. The first thing you should do when you solder anything is to think safety. Always insure that you have adequate general ventiliation and avoid breathing the fumes generated by soldering or solvents. Eye protection is required because solder may splatter. Don't forget to remove all jewelry while soldering. With safety in mind, let's go through the procedure of soldering a wire to an electrical connector (cannon plug).

Prepare the wire by trimming the insulation from the end of the wire—1/32 inch plus the length of the solder cup is usually sufficient. Take care not to cut or nick the individual strands. Stripping can be done with wire strippers or a knife.

After stripping the wire, a slight twist will keep the individual strands together until they are tinned. Tinning the wire involves dipping the copper strands into flux, then coating them with solder. Tin only about half of the exposed stripped wire. Tinning prevents the strands from unraveling as they are inserted into the solder cup of the connector or terminal.

After these preparations are completed, proceed with the soldering operation. Apply flux to the solder cup, then insert the wire. Once the wire is in the cup, touch the tip of the soldering iron to the soldering cup, and at the same time, apply a small amount of solder at the point between the wire and the cup.

The solder melts, floating the lighter flux and impurities to the surface and edges. After the solder melts on all parts of the joint, remove the soldering iron from the cup. The solder cools and forms an alloy with the metal of the wire and cup. In approximately 1 minute, the solder should be hard enough for the connection to be moved. Allow the joint to cool naturally. If cooled too rapidly, a weak joint may result. As a final step, inspect the soldered joint, and remove excessive flux. Most of the flux should have burned away during the soldering process.

Inspecting a Finished Solder Joint. Any of the following indicate a poor solder joint and are cause for rejection:

a. Dull gray, chalky, or granular appearance—evidence of a cold joint.

b. Hair cracks or irregular surface—evidence of a disturbed joint.

c. Grayish, wrinkled appearance—evidence of excessive heat.

d. Partially exposed joint—evidence of insufficient solder.

e. Scorched wire insulation or burned connector inserts.

f. Globules, drips, or tails of solder.

Exercises (078):

1. Why must you wear eye protection when soldering?

2. Why is tinning the wire important?

3. What could happen if solder joints are cooled too fast?

4. If a solder joint has a grayish, wrinkled appearance, what is the problem?

079. Explain soldering procedures for repair of electronic circuits in terms of the devices used, the benefits derived, and operations performed.

Repair of Electronic Circuits. Quite frequently you will be required to repair electrical and electronic circuits using soldering guns and irons. At first glance, this type of maintenance may seem very simple. There is, however, a definite technique involved. Repair practices often appear to be acceptable, but poor soldering is one of the major causes of equipment malfunctions.

Component Removal. Components should be removed from a circuit only when absolutely necessary. Many defects occur in electronic systems because of unnecessary removal of components. When it is necessary to remove a component for testing, always protect the device against overheating.

Heat sinks and overheating. Small resistors, diodes, and transistors are extremely susceptible to excessive heat. The use of a heat sink usually provides sufficient protection for the component. (NOTE: A heat sink is any material or device which is attached to the component being soldered and which will absorb some of the [illegible] being applied.) It is always best to use a heat sink especially designed for the job you are doing. When a commmercial heat sink is unavailable, a pair of needle-nose pliers of the correct size will suffice. Always connect the heat sink between the component or wire and the solder joint. Don't forget to use a heat sink on any other component which may be connected to the same terminal or circuit pad. Otherwise, you may find yourself saving a low-power resistor while destroying an expensive transistor.

Avoid the application of excessive heat to printed circuits. The bond between the metal foil and the board can be ruined by heat, and the foil will peel away.

Wires can also be damaged by the application of too much heat. Heat conduction of the wire may melt the insulation and expose bare wire. This wire must then be replaced or taped. Use the proper soldering heat range for the job. Get in and get out with the soldering iron. Try to avoid continual reheating of the terminal. If done correctly, a component or wire can be removed in a second or two. Desoldering takes practice, but don't practice on a usable board or terminal.

Desoldering. The ungar offset or straight slotted tiplets (D and E, fig. 4-19) will simultaneously melt the solder and straighten the leads and small wires bent against the board or terminal, as illustrated in figure 4-21,A. If this tool is not available, the improvised soldering tip shown in figure 4-20 may be used with a split-end probe and alignment tool (fig. 4-19), or with a pocket penknife as illustrated in figure 4-21,B.

The bar-type tiplet (K, fig. 4-19) will remove straight-line multiterminal parts quickly and efficiently, as illustrated in figure 4-21,C. The removal of this type of part may be accomplished by individually heating each solder connection and brushing away the melted solder with a wire brush, as shown in figure 4-21,D. In using this method, particular care must be taken to prevent loose solder from making contact with other parts or with the circuit board where it may cause a possible short circuit.

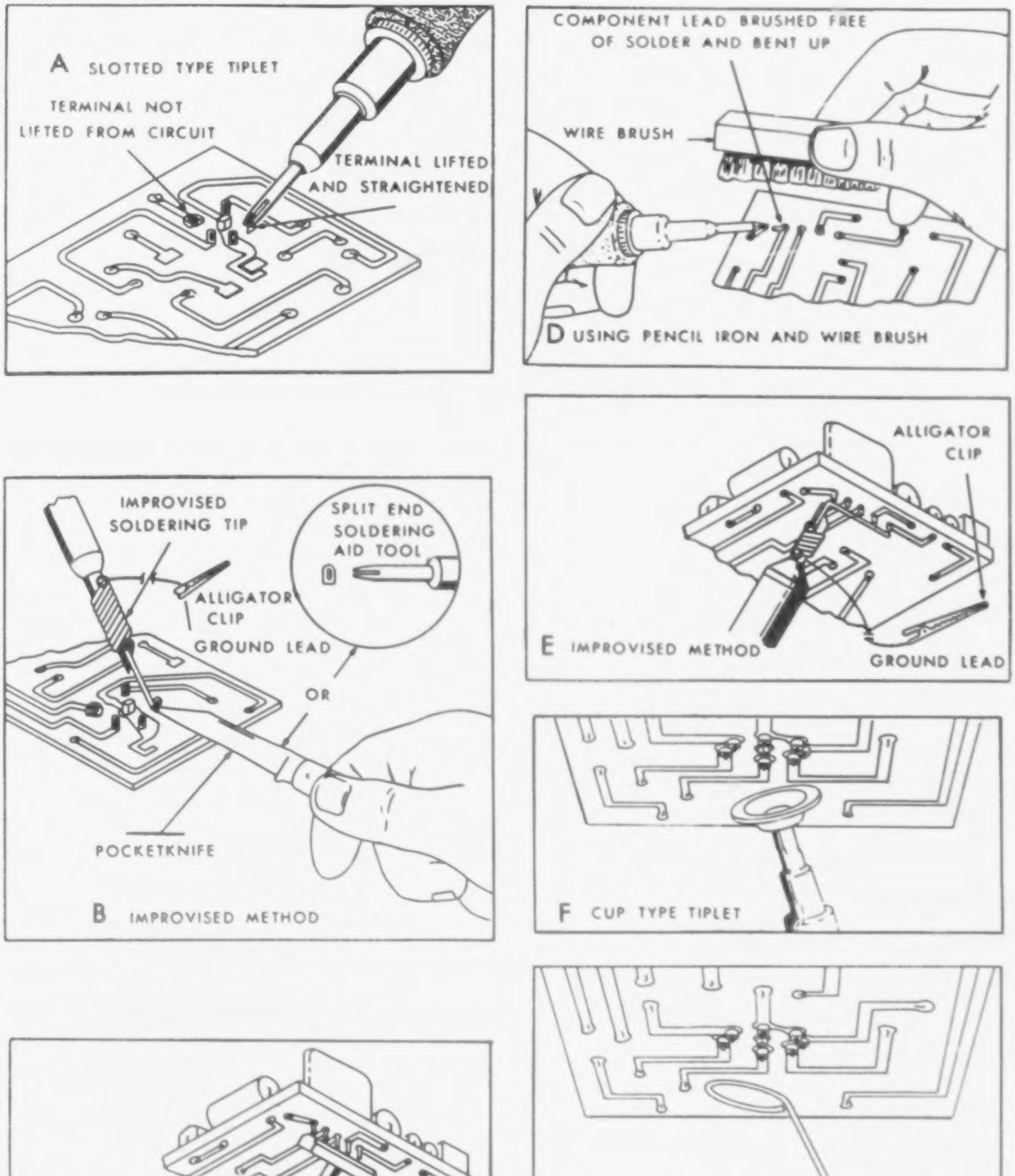
A SLOTTED TYPE TIPLET
TERMINAL NOT LIFTED FROM CIRCUIT
TERMINAL LIFTED AND STRAIGHTENED
COMPONENT LEAD BRUSHED FREE OF SOLDER AND BENT UP
WIRE BRUSH
D USING PENCIL IRON AND WIRE BRUSH
IMPROVISED SOLDERING TIP
SPLIT END SOLDERING AID TOOL
ALLIGATOR CLIP
GROUND LEAD
OR
POCKETKNIFE
B IMPROVISED METHOD
ALLIGATOR CLIP
E IMPROVISED METHOD
GROUND LEAD
F CUP TYPE TIPLET
C BAR TYPE TIPLET
ALLIGATOR CLIP
G IMPROVISED METHOD
GROUND LEAD
C180-30
0-10q

Figure 4-21. Special soldering iron adapations.

Another method involves the use of a piece of No. 10 copper wire. One end is wrapped around the soldering-iron tip, and the other end of the wire is fashioned to cover all of the lug connections simulatenously, as illustrated in figure 4-21,E. Exercise care to insure physical contact with the terminals to be unsoldered and nothing else. Do not allow the tool to remain in contact with the connection for prolonged periods of time. Remove the tool after a short time, wipe off the excess solder and then reapply. This permits the area to cool, thus protecting the circuit board and associated parts.

The cup-shaped tiplets (G, H, and I, fig. 4-19), the triangle tiplet (J), and the hollow-cube tiplet (F), are specially designed to withdraw solder from the circular or triangular mounted parts in one operation, as illustrated in figure 4-21,F. If these tools are not available, an improvised soldering tip can be used for circular or triangular mounted parts in the manner described previously for the improvised tip for straight-line multiterminals. This method of removing circular or triangular mounted components requires the use of No. 10 copper wire with one end wrapped around a soldering-iron tip and the other end of the wire shaped to cover all of the lug connections simultaneously, as illustrated in figure 4-21,G. This tool must be applied with care to the terminals of the part to be removed so as not to touch the circuit board or its associated parts. Components must be replaced on a circuit board or terminal only after all excess solder has been removed.

Component Replacement. When installing new componets, try to avoid excessive bending of the leads. Components such as resistors and capacitors should be mounted slightly above a printed circuit board. The leads must not be bent closer than one-eighth of an inch above the board. This allows room for air circulation and also provides sufficient space for use of a heat sink of the leads.

Once the component has been installed, the leads should be bent over on the foil side of the board. The bent leads should be clipped not less than 1/16 inch from the mounting hold. This provides a good mechanical connection and a sufficient amount of lead to which solder may be applied.

Application of Solder. In the application of solder, remember the iron must heat the metal to solder-melting temperature before actual soldering can take place. Hold the flat side of the soldering iron directly against the parts to be soldered. The solder-melting temperature is reached in a matter of seconds (5 to 10 seconds); therefore, the soldering iron and the solder strand (i.e., wire) can be applied simultaneously. Apply the solder to the point of soldering iron contact, not to the soldering iron. Figure 4-22 illustrates both the correct and incorrect manner of solder application.

Be sure the end of the lead, or any portion of the part to be soldered, has been properly cleaned and tinned before positioning it for soldering. Do not tin printed-circuit terminals; but do remove moisture, grease, or wax from the printed ribbon with a stiff bristle brush and an approved solvent.

A final remark, the prime purpose of soldering is to seal out air and moisture, and thus prevent oxidation at the point of connection. The fact that solder further secures the connection is a bonus. In other words, make your wire connections mechanically strong before solder is applied.

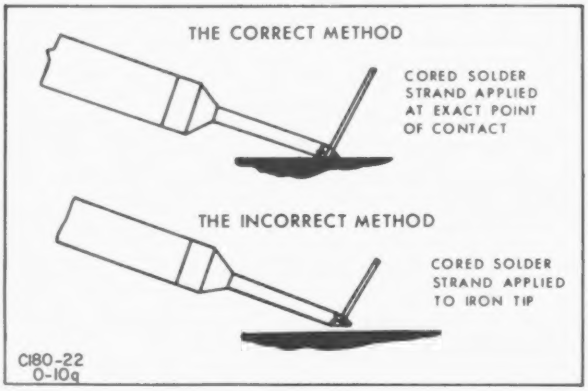
THE CORRECT METHOD
CORED SOLDER STRAND APPLIED AT EXACT POINT OF CONTACT
THE INCORRECT METHOD
CORED SOLDER STRAND APPLIED TO IRON TIP
C180-22
0-10q

Figure 4-22. The correct and incorrect methods of solder application.

Exercises (079):

1. a. What device is used to dissipate heat when removing delicate solid-state devices?

   b. Where is this device connected?

   c. How does it work?

2. a. What may occur if too much heat is applied to an insulated wire?

   b. How may the damage cited above be repaired?

3. What two tasks do you simultaneously accomplish when you use the ungar offset or straight slotted tiplet during the desoldering process?

4. What two benefits are derived from mounting transistors and components at least one-eighth of inch above the board?

5. When applying solder to a connection, state the rule as to where the solder is and is not applied.

4-6. Inspections

Why must we inspect the electrical system? Why not wait until a problem exists before looking for one? You have probably heard these questions before, or maybe you have asked them. You have probably also heard this remark, "I never find anything wrong, so why worry about it?"

080. Cite the purpose of the inspection.

Purpose of Inspection. The primary purpose of the inspection system is to locate and repair equipment before total failure; that is, finding a loose clamp and tightening it before it causes a line to burst, or tightening a microswitch on the landing gear before it comes loose in flight. Maintenance that can be accomplished to avoid major problems later on is important. The Air Force uses several types of inspections, and each one is geared to prevent future malfunctions. To insure that nothing is overlooked during an inspection, the Air Force has developed −6 technical orders which list all items to be checked. By thumbing through the pages of the −6 technical order you will find words such as *loose binding, chaffed, leaking, broken, secure*, etc. the conditions that have in the past caused troubles and generally can be identified by looking and feeling. They can be located and repaired prior to a system failure which could result in loss of an aircraft.

Exercises (080):

1. What is the primary purpose of the inspection system?

2. What directive has been developed to prevent overlooking conditions such as loose binding and leaking?

081. State the reasons for inspecting the electrical systems; list some of the things you should look for during scheduled inspections.

Aircraft Electrical Systems Inspections. Inspections of electrical systems are covered in great detail in Technical Order 8−1−1, Aircraft Electrical System Inspection Procedures. You should become familiar with the contents of this technical order, because it tells you the conditions that should and should not exist in all electrical systems. The items of inspection that pertain only to an electrical system for a particular aircraft are listed on the inspection workcards for that aircraft. For now, let's discuss the items that you should look for in all electrical systems.

All aircraft electrical wiring must be installed so that it is mechanically and electrically sound and neat in appearance. Wires and wire groups should be protected from the following:

a. Chafing or abrasion.

b. High temperature.

c. Possible use as a handhold, or as support for equipment or personal belongings.

d. Damage from cargo being stored or shifted.

e. Damage from personnel moving about within the aircraft.

f. Damage from battery acid or fumes.

g. Damage from volatile fluids or solvents.

h. Abrasion in the wheel well areas.

Wires should be kept away from high-temperature equipment, such as high-wattage resistors, heating ducts, and exhaust pipes. When it is necessary to route wires through hot areas, they must be insulated with fiberglass, asbestos, or teflon. Sometimes conduit may be specified. In these cases, conduit with high-temperature liners or high-temperature plastic tubing must be used.

Check wire and wire groups against chafing or abrasion where contact with sharp surfaces or other wires might damage the insulation. Damaged insulation may result in shorted circuits, malfunction, or inadvertent operation of the equipment. When wires pass through a bulkhead, see that they are installed with a clamp. If the wires come closer then one-fourth inch to the hole, a suitable grommet must be used to protect the wire insulation. If the grommet is used to facilitate installation, the grommet must be cut at a 45° angle. Wires or wire bundles should be installed so that they are protected by the aircraft structure. Conduit should be used to prevent cargo from pinching the wires against the airframe. Wire bundles should be placed so that personnel are not tempted to use them as handholds or ladder rungs.

Wires should be routed parallel to combustible fluid or oxygen lines; however, they should be separated from the lines by at least 6 inches. The wires should be routed on a level with, or above the plumbing lines. The wires should be clamped in such a manner that if a wire breaks at a clamp it will not come in contact with the plumbing line. When the wires must be routed closer than 6 inches from the plumbing lines, clamp both the plumbing line and the wire bundle to the same structure to prevent relative motion. It may also be necessary to use a nylon sleeve over the wire bundle to give it further protection, so inspect for this. Use two cable clamps to maintain separation. The clamps are used for separation only—not for supporting the bundle (see fig. 4-23). Under no circumstances should wires be routed within one-half inch of a plumbing line. Plumbing lines carrying flammable liquids or oxygen should not be used to support wire or wire bundles. Clamps may be used only to insure separation.

Wiring should be routed to maintain a minimum clearance of 3 inches from all control cables. If this clearance cannot be maintained, install mechanical guards to prevent the wire from coming into contact with the control cables.

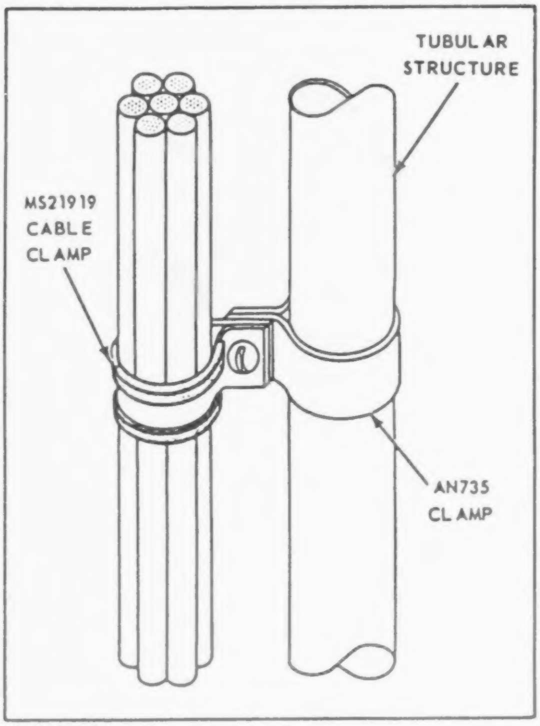

Figure 4-23. Separation of wires from plumbing lines.

Wire and wire bundles must be supported by clamps or grommets at intervals of not more than 24 inches. Plastic clamps may be used providing every fourth clamp is the rubber cushion type. The approved clamp for Air Force use is type MS21919, which is cushioned with insulating material. You should never use clamps without cushioning material to support wire. A type AN735 clamp should be used to clamp wire to a tubular structure (see fig. 4-23).

Rotate wire bundles so that they are parallel to the rib structure of the aircraft or at right angles to the rib structure. Install wires or wire bundles so that the slack between the clamps will not exceed one-half inch with normal hand pressure. The slack must never be so great that the wire or wire bundle can come in contact with a surface that might cause abrasion. However, there must be sufficient slack to do the following:

a. Permit easy maintenance.

b. Allow replacements of terminals at least two times.

c. Permit free movement of shock-mounted equipment.

d. Permit shifting of equipment for maintenance purposes.

Wire bundles inside junction boxes are to be supported by cushioned cable clamps across hinged doors. The correct method is to twist the wires across the hinge when the door is opened. The incorrect method causes the wires to bend when the door is opened, and this bending damages the wire or insulation.

Wire bundles are to be attached to the walls of junction boxes in such a manner that there is no chafing against the terminal studs, or other components in the box. Any slack that is required for terminal rework is to be tied to prevent snagging. These are just a few examples of what you should look for on an inspection. You must use inspection cards for the aircraft you are working on and the inspection you are performing.

Exercises (081):

1. What are the reasons for inspecting the electrical systems?

2. What technical order covers electrical system inspection procedures?

3. How should wiring be routed in regard to combustible or oxygen lines?

4. What is the maximum interval for support clamps when installing wire bundles?

082. Explain why you use a composite toolkit.

Composite Toolkit. The composite toolkit (CTK) program is a tool control system designed to reduce foreign-object damage (FOD). The program also permits maximum use of existing tools, reduces theft potential, reduces the capital investment in tools, and improves the overall condition of the tools you use. The CTK program works through a strict accountability system and an easy method of tool inventory.

The deputy chief of maintenance (DCM) will usually publish an MOI (maintenance operating instruction) to implement the CTK program. Depending on local conditions, CTKs may be developed by task, workbench, engine station, or for an engine shop or workcenter. The maintenance man or woman should have the number and type of tools required to do the job.

Some ways of CTK tool control are:

a. Identify all CTKs and tools contained therein by a number or color code.

b. As many identical tools as necessary may be included in a CTK. Do not display more than one tool per silhouette, label, or cutout except for tools issued in sets, such as drill bits and Allen wrenches. These may be kept in the box or holder issued with the set.

c. When a CTK contains several dispatch kits in tool bags, pouches, or similar holders, and the primary purpose of the master CTK is storage and security, inventory the kit prior to placing it into the storage CTK.

d. Control apex bits similar to other tools by shadowing or recessing (it is not necessary to number or color code). In workcenters such as flight line where pouches or lineman kits are used and one type apex bit (example, #4 bit) is needed, the workcenter supervisor may issue an apex to each pouch. Inventory the apex bit along with the other tools prior to placing the pouch in the CTK. Extra apex bits are controlled by the supervisor and issued on a one-for-one basis.

e. The workcenter supervisor or designated representative inventories all CTKs at the beginning and end of each shift. Inventory CTKs or toolboxes maintained for TDY or mobility requirements prior to use, after use, and quarterly.

f. Use a tag control system when individual tools are removed from CTKs to be used outside the immediate work area. Tags are not required for CTKs used to perform maintenance in the shop or in the immediate area of an aircraft when individual tools are shadowed.

g. Use color codes to identify missing tools or tools on requisition. Red tags indicate missing tools. Yellow tags indicate tools on requisition. Dispose of unserviceable tools.

You should remember to account for your tools at the start and finish of each job. Any time a tool cannot be found after working on an aircraft, you must red-X the aircraft forms.

Exercises (082):

1. What is the main reason for using CTKs?

2. What makes the CTK program work?

3. How are tools in a CTK identified?

4. When should you inventory your tools?

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Batteries and Servicing Equipment

THE AIRCRAFT BATTERY is one item that is taken for granted by most aircraft maintenance personnel. During an emergency, it could well be the heart of the aircraft; insomuch as it could keep the aircraft's electrical systems operating. Not only is the battery important but so are the personnel who service them, the servicing equipment, and the charging equipment. Unless you know and understand batteries, you will not be able to function effectively as an electrician. If you have ever worked in a battery shop, you know there is more to batteries than just removing and replacing them in the aircraft. Servicing and charging equipment must be kept in good condition. The shop must be kept clean and well organized for safety reasons. These and other items are discussed in this chapter.

5-1. Battery Shop Operation

The number of personnel assigned to a battery shop varies depending upon mission requirements, types of aircraft, and how many people are assigned to the electric shop. You could be assigned to the battery shop for a specified period of time, or you may have to work in the battery shop as the need arises. In either case, you should be familiar with the operational procedures of the battery shop as well as the safety equipment. But most important, be familiar with all the equipment before operating any of it.

083. Cite some basic precautions to follow when working in a battery shop.

Precautions. Battery shop operation must conform to pertinent Air Force directives and the National Safety Code. Working in a battery shop requires the same high degree of job proficiency as does working on the aircraft on the line. After all, the battery that you service will have to meet certain requirements when installed in the aircraft. How well it performs depends on how well you know and do your job. It is very important that all battery shop personnel are thoroughly trained in their tasks and indoctrinated in safe operating procedures.

The base you are assigned to may have had the same battery shop for years. How it is arranged may or may not be completely efficient. If you see something that will help improve the efficiency of the shop, discuss it with your supervisor.

Service nickel-cadmium batteries in an area isolated from lead-acid batteries. To avoid an explosive or toxic condition, sufficient ventilation must be provided to prevent acid fumes generated in the lead-acid battery shop from entering the nickel-cadmium battery shop. Keep the specific equipment for the two kinds of batteries separate and carefully labeled to avoid accidentally getting them in the wrong shop. This is to prevent electrolytes from contaminating each other which, in turn, can establish an explosive condition. To avoid accidental shorting or arcing of battery cells, do not lay tools or metal items on or in close proximity to them. Make sure that rings or other jewelry are not worn while working in the battery shop. The above practices have all too often resulted in personal injury when electrical arcs have caused severe burns or ignited an explosive atmosphere. Insure that the lead-acid battery-charging equipment is located in well-ventilated fireproof rooms. Excessive boiling of the electrolyte in lead-acid batteries during charge should not be permitted since hydrogen gas creates a highly explosive gas mixture in the shop's atmosphere. Therefore, there must be NO smoking in battery shops.

Be very careful when handling electrolyte. To avoid acid or chemical burns, be certain that shop personnel wear electrolyte-proof goggles or full faceshields; also insure that rubber gloves and aprons and acid-resistant safety shoes or rubber knee-length boots are used. When mixing electrolyte always pour the acid solution slowly into the water. NEVER pour water into the acid. The heat of dilution will cause the water to boil and possibly splatter on shop personnel. Other precautions are listed below:

a. Racks and trays must be resistant to electrolyte. Racks must be designed to permit free access for servicing batteries.

b. Floors must be resistant to or protected from electrolyte accumulation. Materials/equipment must be provided for neutralizing or flushing spilled electrolyte.

c. Facilities for quick drenching of the eyes and body must be provided. A container (approximately 1 quart) of water equipped with an eyewash cup of water for drenching purposes is adequate; however, a special eye-washing fountain which rinses both eyes simultaneously is excellent.

d. The battery bank should be located in an area of minimal personnel and vehicle traffic. Separate rooms are desirable.

e. NO SMOKING signs must be posted in the area.

f. Fire extinguishers must be provided.

g. Cells of the unsealed-jar type will NOT be used.

h. Personnel assigned to work with batteries must be instructed in emergency procedures.

i. Electrolyte must be mixed in a well-ventilated area. Acid or alkaline will be poured gradually, while stirring, into the water. Water will never be poured into acid solutions.

j. Electrolyte must never be poured into metal containers or stirred with metal objects.

k. When taking specific gravity readings, always place an electrolyte-resistant gloved finger over the end of the hydrometer while moving it from cell to cell to avoid splashing or dripping of the electrolyte.

Exercises (083):

1. State the basic precaution to use when mixing electrolyte.

2. Name three items that must be provided for the workers' protection when working in the battery shop.

3. What important task should the supervisor perform when anyone is assigned to battery shop work?

5-2. Types of Batteries

In this section we discuss constructional features of lead-acid and alkaline batteries. To understand batteries, you should have some idea of their construction. We begin our discussion with the lead-acid battery.

084. State constructional features and operational principles of the lead-acid battery.

Lead-Acid Battery. There is no basic difference between an aircraft's lead-acid battery and that of automobile batteries. Both have the same type of lead plates immersed in a solution of sulphuric acid and water. The aircraft battery, however, requires certain modifications because of the unusual conditions under which it operates. For example, aircraft batteries are built so they will not leak when the airplane is flying upside down. Also, aircraft equipment uses 24 volts rather than 12 volts, as used on most of today's cars. This higher voltage permits the use of smaller wires for transmitting a given amount of power; also it permits aircraft components to be made smaller and lighter. The capacity of aircraft storage batteries is generally less than the capacity of those used for automobiles, since heavy current flow is required for starting an automobile engine, while an aircraft normally uses special starting units, carts, or devices to start their engines. The criticality of having operational batteries available in an airborn aircraft, and their generally smaller capacity dictates that they receive frequent and careful maintenance.

Construction. The plates used in lead storage batteries consist of a grid, or framework, which supports the active material. The grids, cast from an alloy of lead and antimony, are rectangular in shape.

The positive plates are made of commerical red lead with the active material consisting of a mixture of lead peroxide and lead sulphate. The negative plates are made of yellow lead oxide with the active material consisting of a mixture of sponge metallic lead and lead sulphate. These mixtures are applied to the plates, and when the plates are fully charged, there will be very little lead sulphate remaining in either the positive or negative plates.

The positive and negative plates must be electrically insulated or separated from each other so they cannot touch. Thin porous sheets of insulating material called "separators" are inserted between each positive and negative plate for this purpose. The separators are made of microporous rubber or wood to permit easy flow of electrolyte through them.

The total amount of current a cell can deliver is referred to as its capacity. The capacity depends on the amount of material available for chemical action. Since the capacity of a single plate is relatively small, a number of plates are grouped together. The capacity of a battery can be increased by increasing the size and/or number of plates in the battery.

A cell is an assembly consisting of a postitive and negative group of plates immersed in a solution of sulphuric acid and water. The nominal voltage of a cell is approximately 2 volts regardless of size or number of plates. Its capacity depends upon the size, thickness, and number of plates in each cell.

Batteries are made up of groups of cells connected in series by lead connectors welded to the cell posts. For a 24-volt battery, you would need 12 cells.

Spillage and leakage of electrolyte when maneuvering or flying upside down is prevented by the design of the vent cap. The nonleakable vent cap has a conically shaped lead insert. This acts as a vent when the plane is flying right side up, but drops against the relief opening to prevent leakage when the battery is upside down.

A law of physics states that: "Energy may neither be created nor destroyed but may be changed from one form to another." The battery is an example of how this law works. Electrical energy put into the battery by a charging device is changed into chemical energy. The battery stores this energy until it is needed and then changes the chemical energy back to electrical energy.

Ratings. The capacity of a lead-acid battery, or the total amount of electrical energy a cell can deliver, depends entirely upon the amount of material available for chemical action. Therefore, to increase the capacity of a battery, a greater number of plates or larger or thicker plates must be used in each cell with enough electrolyte to react with the active material. As a battery sheds active material during charge and discharge, its capacity becomes gradually less.

Capacity is measured in ampere hours, which is the number of amperes flowing from the battery on discharge at a given temperature and down to a given voltage, multiplied by the time in hours the battery will deliver this current. For example, a battery discharged at 2 amperes for 10 hours would furnish 20 ampere-hours. This could be replaced by charging the battery at 5 amperes for 4 hours or 1 ampere for 20 hours.

The capacity rating of aircraft batteries is based on the maximum current which they will deliver for five hours, with a starting temperature of 80° F and a final terminal voltage of 1.75 volts per cell. This is called the battery's "5-hour discharge rate" and the rated capacity of the battery is this rate multiplied by 5. For instance, a battery which discharges 6.8 amperes for 5 hours under the above conditions is rated at 6.8 times 5 = 34 ampere-hours capacity.

A second rating applied to aircraft batteries is based on the maximum current they will deliver for 5 minutes, with a starting temperature of 80° F and a final average terminal voltage of 1.2 volts per cell. This rating is called the "5-minute discharge rate" and is a measure of the battery's ability in normal starting.

The capacity of a battery appears to be lower at a high-discharge rate than at a low rate. This is due to the inability of the electrolyte to distribute the charge uniformly through the plates when the surface is being discharged so rapidly. In other words, although the surface of the plate is discharged and the internal resistance of the cell thereby increased, the interior of the plates is still charged. Under these conditions, the battery will recover in a short time and discharge may be continued again. This is particularly true of a cold battery which, even though fully charged, will deliver only about 5 percent of its capacity at a high discharge rate and will crank an engine for only a very short time. For example a 34-ampere-hour battery at −20° F will deliver only 2.5 ampere-hours at a discharge rate of 150 amperes, which it will maintain for only three-fourths of a minute. The battery is then apparently completely exhausted and will not crank the engine. It will recover after a few hours if allowed to stand idle.

When an aircraft, located in a below-zero temperature, is not in use, its battery should be removed and kept in as warm a place as possible or heated in the aircraft. DO NOT attempt to keep the battery warm by charging, as continued overcharging is detrimental to its life. When available, always use external power for cranking engines and conserve the battery for flying operations.

Exercises (084):

1. Of what does a lead-acid battery's electrolyte consist?

2. What are the thin porous sheets of insulating material in the battery called and for what are they used?

3. How is spillage or leakage prevented in aircraft batteries?

4. How is capacity measured in lead-acid batteries?

085. State construction features and operational principles of the nickel-cadmium battery.

Nickel-Cadmium Battery. While many batteries use acid electrolytes, some use an electrolyte that is an alkaline chemical. The nickel-cadmium (Ni-Cad) battery falls under the alkaline-battery category. Ni-Cads are used in many of today's modern aircraft so, as an aircraft electrical systems specialist, knowing how these batteries are constructed and how they perform is essential.

Nickel-cadmium batteries derive their name from the composition of their plates: nickel oxide on the positive and metallic cadmium on the negative. These batteries have several major advantages over other types of storage batteries:

a. They will maintain a relatively steady voltage when being discharged at high currents.

b. They can be charged and discharged at a high rate without causing permanent damage.

c. They can stand idle in any state of charge for an indefinite period of time without damage.

d. They can withstand extremely cold temperatures without damages.

e. They are not subject to failure by vibration or severe jolting.

f. They do not normally exude corrosive fumes.

g. They are composed of individual replaceable cells.

h. They have an extremely long service life.

Construction. Nickel-cadmium batteries for 24-volt aircraft systems contain 19 individual cells. These cells are connected in series. Each cell has a nominal open-circuit voltage of 1.25 volts.

Separators are made of nylon and cellophane or from a new material called Permion. (Refer to fig. 5-1). The separator's task is to keep the negative and positive plates from coming into contact with each other. In preparing the cell assembly, the continuous separator is interposed between the plates as each successive plate is added. The plates and separators are assembled to make cell cores.

The cell is assembled into its final form by welding the tabs of the negative plates to one terminal post and the tabs of the positive plates to a second terminal post. Once assembled, it is inserted into a plastic case and fitted with a cover-and-vent assembly that permits the terminal posts to project through the top of the case. The compete unit is then sealed, but the venting system allows excess gases to escape.

Each cell is equipped with a vent plug and fillercap. It can be removed for cleaning or adjustment of the electrolyte. When excessive gases develop in the cell during charge, they escape through the venthole. The vent relieves gas pressures by remaining closed until a pressure of 2 to 10 psi is reached, at which time it opens. Except when releasing gas, the vent remains sealed to prevent electrolyte leakage, the entry of foreign material into the cell, or contamination of electrolyte by exposure to air high in carbon dioxide content.

The electrolyte used in nickel-cadmium batteries is a 30-percent solution by weight solution of potassium hydroxide (KOH) in distilled water. It provides a conducting path for

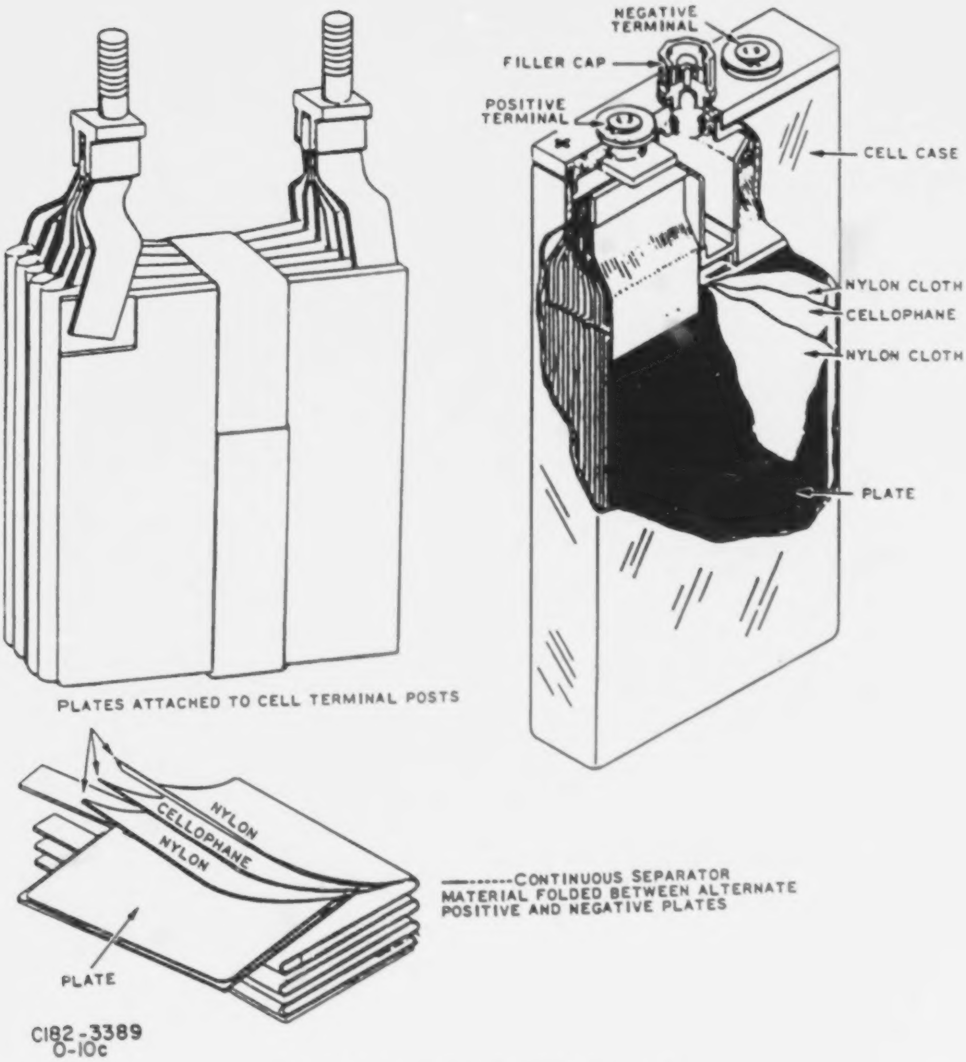
NEGATIVE TERMINAL
FILLER CAP
POSITIVE TERMINAL
CELL CASE
NYLON CLOTH
CELLOPHANE
NYLON CLOTH
PLATE
PLATES ATTACHED TO CELL TERMINAL POSTS
NYLON
CELLOPHANE
NYLON
CONTINUOUS SEPARATOR MATERIAL FOLDED BETWEEN ALTERNATE POSITIVE AND NEGATIVE PLATES
PLATE
C182-3389
0-10c

Figure 5–1. Construction of a nickel-cadmium cell.

the current which flows between the positive and negative plates. The electrolyte does not take part in the chemical reaction in nickel-cadmium batteries but acts as an ion carrier. The specific gravity remains constant at 1.300 whether the battery is in a charged or discharged state; therefore, specific gravity cannot be used to measure the battery's state of charge.

Charging. When charging current is applied to the cell, the cadmium-oxide material of the negative plates gradually loses oxygen and becomes metallic cadmium, and the nickel-oxide active material of the positive plate is brought to a higher state of oxidation. These changes continue in both sets of plates as long as the charging current is applied or until the active materials of the plates have been completely converted. The cell emits gas toward the end of this process because of the decomposition of the water component of the electrolyte in hydrogen at the negative plates and oxygen at the positive plates. The electrolyte conducts current between the plates of opposite polarity and reacts to produce the electrochemical changes without producing any significant change in its own overall chemical composition. Thus, the measurement of specific gravity of the electrolyte gives no indication of the state of charge in a nickel-cadmium cell. During discharge, the chemical reaction is reversed. The positive plates gradually return to a state of lower oxidation, while the negative plates simultaneously regain lost oxygen.

The optimum operating temperature for typical nickel-cadmium cells is in the range of 80° to 90° F, and an increase or decrease in temperature from that range causes a corresponding reduction in cell capacity.

A nickel-cadmium battery is capable of being charged at rates many times its rated capacity for short periods. Example: A 34-ampere-hour battery, at 80° F, can be charged at 170 amperes (or 5 × 34) for 5 minutes. At temperatures higher or lower than 80° F, the charging characteristics change rather quickly. At high- and low-temperature charge, acceptance and charge efficiency are both greatly reduced. It is not advisable to start charging above 100° F. A nickel-cadmium battery can be fully charged by constant current. Constant potential charging, as occurs in the aircraft, does not fully charge a nickel-cadmium battery.

A fully charged battery that receives proper maintenance and regular capacity checks will provide very high rate discharges over a wide range of temperatures. By comparison, a nickel-cadmium battery will provide more than twice as much power as a lead-acid battery of equivalent weight and volume

One subject that should be mentioned about Ni-Cads is "thermal runaway." Basically, thermal runaway is an uncontrollable rise in battery temperature that can ultimately destroy the battery and create havoc for the aircraft and crew. Two conditions necessary for runaway are elevated battery temperature and overcharging. This is why it is so important to follow TO procedures when charging batteries. Ni-Cad batteries discharge at high rates and take on new charges at equally high rates. A typical failure sequence is as follows:

(1) Battery is in a low state of charge.

(2) Battery draws a high charging current (during or after engine start) causing the temperature to increase.

(3) When the battery becomes charged, it is hot as a result of the high charge rate. The hot battery has a slightly lower voltage which causes overcharging to begin. The cellophane in the plate separators, which acts as a gas barrier in the cells, is destroyed by overcharging. Its destruction allows the oxygen gas generated at the positive plate to recombine with the active material in the negative plate, generating a large amount of heat and possibly leading to thermal runaway.

(4) The higher current flow causes an increase in temperature and vice versa. This cycle is self-perpetuating and continues until one or more cells short completely.

(5) If the battery is not disconnected from the charging source, overcharging continues and can accelerate to a point that results in fire or explosion.

Capacity. When temporary loss of capacity occurs, the battery is unable to deliver its rated design capacity. This loss of capacity is caused by shallow discharging associated with aircraft use and recharging by means of constant potential (voltage). With time, a battery installed in an aircraft and floating on the aircraft bus will experience a loss in capacity.

The nature of this loss in capacity is due to the buildup of a film on the surface of the plates in the cells. The rate of this film buildup in the individual cells reduces active plate area, thus increasing current density and reducing battery capacity. At the same time, cell imbalance is occurring because of differences in the rate of this buildup, charge efficiency, and self-discharge taking place.

The positive way by which this charactristic can be compensated for is through constant current charging in the battery shop. Through proper maintenance, the cell imbalance and the loss-of-capacity can be corrected. This will be covered later in this chapter.

The temporary loss-of-capacity effect should not be taken lightly. Even though a battery may appear to be giving satisfactory performance, it may deliver only a portion of its rated capacity if required during an emergency. For example: During a test being conducted on nickel-cadmium batteries, 30 batteries of 34 ampere-hour (Ah) capacity were removed from aircraft and given a capacity test. The average capacity measured on the 30 batteries was less than 15 ampere-hours, or less than half of the rated capacity; two of the batteries delivered only 2 ampere-hours each. Although inadequate aircraft-charging voltage may have contributed to some of the low capacities, it is clear that the condition of the batteries would not be ideal under emergency conditions.

In order to minimize the loss-of-capacity problem, nickel-cadmium aircraft batteries should be removed from the aircraft periodically and recharged by a constant current.

Batteries that are held in the battery shop in a ready-for-issue status require special attention in order to provide fully charged batteries for issue. Charge those only batteries which are required for issue within a week. The others should be processed up to the final charge and held in the shorted condition until a requirement is known. The rate of discharge for charged batteries is approximately 1.2 percent per day in storage at normal temperature. At this rate, a battery would deliver about 85 percent of its rated capacity 2 weeks after charge. The self-discharge rate may be as high as 10° percent per day at 120° F. In storage at temperatures near 0° F, the loss is in the order of 1.5 percent per month. The rate of discharge will also be affected by cell-to-case current leakage. Normally all batteries in base supply are maintained in a ready-for-issue or ready-for-charge status.

Exercises (085):

1. Of what do the plates of a nickel-cadmium battery consist?

2. What voltage measure is the open-circuit voltage of a Ni-Cad cell?

3. From what are the separators in the Ni-Cad made?

4. At what point does the vent cap rlease gas pressure?

5. Of waht is the electrolyte in a Ni-Cad a mixture?

6. What is thermal runaway?

5-3. Charging Batteries

New batteries, as well as old batteries, require more than just everyday maintenance and care. They also need to be charged when new—and from time to time when they become weak. At any rate; knowledge of the battery-charging equipment and how to connect batteries to the charger is important. This is true of the lead-acid battery as well as the alkaline. In this section, we will discuss the chargers used on both types of batteries.

086. Cite procedures used to charge, discharge, and test nickel-cadmium batteries.

Testing and Charging Nickel-Cadmium Batteries. There are several types of battery chargers/analyzers available today. For our discussion, we will use the Model 505–50–1M which is very common. This charger/analyzer performs two functions: It charges the nickel-cadmium battery by the constant-current method and it discharges it. You can charge one battery and discharge another at the same time.

Capacity testing and discharging the battery. When a nickel-cadmium battery is brought into the shop, you must clean it, inspect it, and perform a capacity check. A capacity check is measuring the discharge rate of the battery on the charger/analyzer and recording the amperage and time. These values are then checked against the table in TO 8D2-3-1, *Operation Service and Repair Instruction—Aircraft Nickel-Cadmium Storage Batteries*, for the particular battery under test. After the first hour, monitor individual cell voltages at 15-minute intervals. Mark any cells having voltages of .95 or below. When an individual cell reaches .5 volts, it should be shorted out to prevent polarity reversal within the cell.

To determine if a battery has passed or failed the capacity test, the following criteria are used:

a. Batteries in which all cell voltages remain above .95 volt throughout the 2-hour discharge period are acceptable and have passed the capacity test.

b. Batteries in which one or more cell voltages decrease below .95 volts during the discharge period have failed the capacity test. Mark those cells, because they must have three chances to pass the capaciaty test. If the cell failed three times, it must be rejected.

By using the charger analyzer, the nickel-cadmium battery can be discharged during capacity test down to 18 volts. After that, a dummy load may be attached to the battery to drain the cell voltages from .95 volts per cell to .5 volts per cell. Then the cells can be equalized.

Cells must be equalized at least once during the battery shop maintenance sequence. Each nickel-cadmium battery must be equalized following an acceptable capacity test and prior to charging. Equalizing is nothing more than shorting out all 19 cells as each individual cell drops below .5 volts. This is accomplished by using shorting bars. The shorting bar on each cell must remain in place for at least 8 hours. This must be accomplished before starting the charging process.

Once the Ni-Cad battery has passed the previous tests, it is ready to be disassembled, cleaned, and repaired as necessary, according to the instructions in the TO. After it is reassembled, it is then ready for the battery charger.

Charging by constant-current method. The way to charge a Ni-Cad battery in the battery shop is by the constant-current method. Even though the Ni-Cad battery can be operated in any position, it must be charged in the upright position to prevent the loss of electrolyte. The vent caps should be loose and in place during charging. Ni-Cad batteries are never charged while connected in parallel.

Before placing the battery on charge, remember to remove all shorting devices from the cells. The battery can then be charged in accordance with the appropriate TO. Check the battery temperature often during the charging process. If it becomes warmer than 115° F (41° C), it may be necessary to add water to the affected cells. The water can be added by using a small squeeze bottle to inject it in the individual cells.

Always use distilled water as tap water contains impurities that shorten the life of Ni-Cad batteries.

The level of the electrolyte should be adjusted, but only if required, after the battery has been completely charged and allowed to rest for at least 2 hours and not more than 72 hours. Check the electrolyte level as follows:

(1) Remove each vent plug and insert a clear plastic or glass tube vertically into the cell.

(2) Place a finger over the top of the tube and withdraw the tube until the end is visible. There should be one-eighth inch of electrolyte in the tube.

(3) If the electrolyte is low, add small amounts of pure distilled water as necessary. Do not remove excess electrolyte unless cells overflow during charge.

(4) Reinstall vent caps after adjustment.

The final step in the charging process is to check for current leakage. A current leakage greater than 50 milliamperes between the battery case and either the positive or negative terminal of the battery is excessive. To isolate a leaky cell, follow these procedures:

(1) Obtain a voltmeter of 1000 ohm-per-volt and place one probe of the meter on either the negative or positive terminal of the battery. Place the other probe of the meter to a paint-free surface on the case and observe the meter reading. Reverse the position of the probes if the meter reads backwards. If leakage is discovered, keep one probe on the battery case and move the other probe systematically from one cell terminal to another, noting voltage readings. Voltage readings will decrease and finally go to negative, indicating the leaky cell has been located.

(2) Mark the point of leakage.

(3) Discharge, disassemble, clean or replace the defective cells, and recharge.

If the battery had passed the capacity test the first time, there is no need for another capacity check.

Exercises (086):

1. By what method is the nickel-cadmium battery charged?

2. After they are cleaned and inspected, what check must be performed on all nickel-cadmium batteries that are brought into the shop?

3. When are the cells of a Ni-Cad battery considered equalized?

4. How many chances must you give a cell to pass the capacity test before the cell is condemned?

5. At what voltage is the shorting device placed on the Ni-Cad battery?

6. When adjusting the electrolyte level in a Ni-Cad battery, how far above the plates should the level be?

087. Cite methods to maintain charging equipment.

Charging Equipment. You may be required to maintain charging equipment at your base. This will include many things—from keeping the equipment clean to performing inspections and repairing the equipment. We will continue our discussion about the Model 505-50-1M battery charger/analyzer.

Description. The battery charger is housed in a steel cabinet. A hinged front panel contains all operating controls and indicators. Charge and discharge circuit breakers and battery connectors are mounted on a smaller panel located below the hinged front panel. The hinged front panel and a hinged door on either side of the front panel provide access to the internal parts of the battery charger. Two removable plates at the rear provide access to rear-mounted parts. Natural convection air cooling is provided by side and rear louvers, bottom holes, and a screened vent at the top. Two eyebolts at the top of the battery charger facilitate lifting. Mounting holes at the inside bottom provide tiedown means. A compartment at the base provides storage space for battery cables and the instruction manual. One complete discharge cable and one charge cable are supplied with the battery charger.

We will not go into the troubleshooting and repair of the battery charger in this CDC. When problems develop with the equipment, you should always refer to the proper technical order for instructions.

Inspection. You have already learned why we inspect aircraft. The equipment we use in the shop is also inspected at regular intervals. Table 5-1 shows the minimum inspection requirements for maintaining the battery charger.

Exercises (087):

1. How are the battery charger parts *cooled?*

2. How often should the meters be inspected?

3. When inspecting the cables, what should you be looking for?

088. Explain procedures to follow when servicing and charging lead-acid batteries in terms of the methods used and the purpose of specific procedures.

Charging Lead-Acid Batteries. A storage battery is charged by passing a direct current into the battery in a direction opposite to that of the discharge current. Because of the resistance within the battery, the voltage of the charging source must be greater than the open-circuit voltage of the battery. For example, the open-circuit voltage of a fully charged, 12-cell, lead-acid battery is approximately 26.4 volts (12 x 2.2 volts). Therefore, a minimum of approximately 28 volts is required to charge it. This larger voltage offsets the voltage losses in the battery due to internal resistance. You can charge batteries by one of two methods, the constant-current method or the constant-potential method.

Constant-current method. In this method of charging, the current is maintained at a predetermined value throughout the entire period of charge. The recommended charging rate for aircraft batteries is determined by the manufacturer. TO 8D2-1-31, *Operation and Service Instructions, Aircraft Storage Batteries,* contains a table which lists the charging rate of most lead-acid batteries used by the Air Force. The table lists the charging rates for new batteries (initial charge) as well as for batteries that have been in service and are in the shop for normal charging.

There may be a time when you are required to charge a battery that is not listed in the TO. What charging rate should you use? A general rule to use in a case like this is to charge the battery at a rate which is 10 percent of the ampere-hour capacity of the battery. For an example, if you had to charge a 44 ampere-hour battery, you could charge it at 4.4 amps. You should use this rule only when you cannot find the battery listed in a TO.

It is not necessary to have a separate charger for each battery undergoing charge. Some constant-current charging installations have a separate charging outlet for each

TABLE 5-1
MINIMUM INSPECTION REQUIREMENTS FOR MAINTAINING THE BATTERY CHARGER

Item	Procedure	Period
Transformers	Inspect for dirt, loose mounting hardware, and loose terminal connections.	3 months
Meters	Examine for loose mounting and loose connections, and cracked or dirty cover glass. Make certain that the meters indicate zero when all power is turned off.	1 week
Rectifiers	Inspect for dirt, corrosion, and bent or loose plates.	3 months
Adjustable wire wound resistors	Examine for dirt, chipping, cracks, blistering, and discoloration. Check for loose connections.	3 months
Rotary switches	Inspect for dirt, bent or broken contacts, and binding.	3 months
Relays	Inspect for dirt, corrosion, pitted or burnt contacts, and sticking armature.	3 months
Potentiometers	Check for dirt, loose mounting hardware, and binding or rough operation.	3 months
Cable connectors	Inspect for dirt, corrosion, and loose, bent, or broken contact pins.	1 week
Cables	Inspect for damaged or deteriorated insulation, loose terminals, and broken wires.	3 months
Cabinet	Check for dirt, dents, scratches, and corrosion. Check doors and hinged panel warping and binding. Check for loose or missing hardware.	3 months

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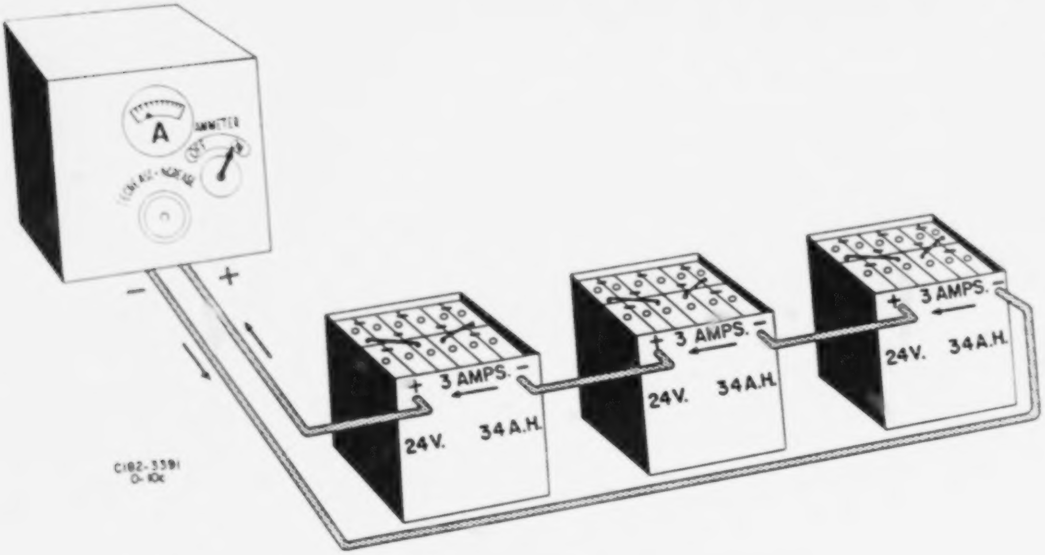


Figure 5-2. Constant-current charging, batteries of the same capacity.

battery, as well as an entirely separate set of manual controls. With this type of installation, you can adjust the individual charging rate of each battery. The most frequently used constant-current charger in service today is the rectifier bulb-type charger. This unit can charge as few as 3 cells (a 6-volt battery) at the minimum charging rate required (1 ampere) or as many as 36 cells (three 24-volt batteries) in series at the maximum rate of 6 amperes at one time.

This charger requires little maintenance. The most common malfunction that you will encounter is a burned-out rectifier bulb. You can replace the bulb very easily by following the procedures in the applicable TO. A word of caution: Always disconnect the charger from the power source before performing any maintenance.

When you charge batteries by the constant-current method, connect them in series, as shown in figure 5-2. Connect the positive terminal of the battery to the positive terminal of the charger and connect the negative terminal of the battery to the negative terminal of the charger. After you complete the connections, place the charger in operation and rotate the manual adjustment until the ammeter gives a charging indication. Batteries can be and have been connected backwards. If this ever happens to you, take this action: Discharge the battery at a slow rate and recharge it correctly. The charging current is determined by the ampere-hour capacity of the smallest battery in the string.

If you connect batteries of 11-ampere-hour, 17-ampere-hour, and 34-ampere-hour capacities in series for charging, you must set the charging rate of 1.1 amperes (the normal service charge rate of the 11-ampere-hour battery). The 11-ampere-hour battery would then be charging at its normal service charge rate. However, the 17-ampere-hour and 34-ampere-hour batteries would be charging at reduced rates. This reduced charging rate would increase their charging time and would decrease the efficiency of the charging equipment. Most battery shops make it a common practice to place batteries of the same capacity together in one charging string so that maximum charging may be accomplished with the equipment available. When charging batteries of different capacities, you may connect two smaller capacity batteries having similar voltage and capacity in parallel and then connect the charging circuit in series with a larger capacity battery. A setup of this type is shown in figure 5-3. You may connect many different combinations of batteries of various sizes in this manner to make more efficient use of the charger. You can compute the approximate charging time of a completely discharged battery by dividing the ampere-hour capacity of the battery by the charging rate. An example of this would be a battery which has a 34 ampere-hour capacity and a charging rate of 2.5 amps. Dividing 34 by 2.5 would give you an approximate charging time of 13½ hours.

Constant-potential method. In this method of charging, you maintain the voltage at a predetermined value throughout the entire period of charge. The recommended charging rate is 14 volts for 12-volt batteries and 28 volts for 24-volt batteries. The charging source can be a motor-driven generator, a DC-generator test stand, or a rectifier. Connect the batteries to be charged in parallel to the charging source, as illustrated in figure 5-4. Each battery automatically draws a current according to its state of charge and its ampere-hour capacity. The charging rate at the start of charge is somewhat higher than normal, but the rate decreases gradually as the battery becomes charged.

Most constant-potential chargers in use today provide only a 28-volt charging source. With this in mind, how do you charge 12-volt batteries? To do this, you connect two 12-volt batteries of the same ampere-hour rating in series

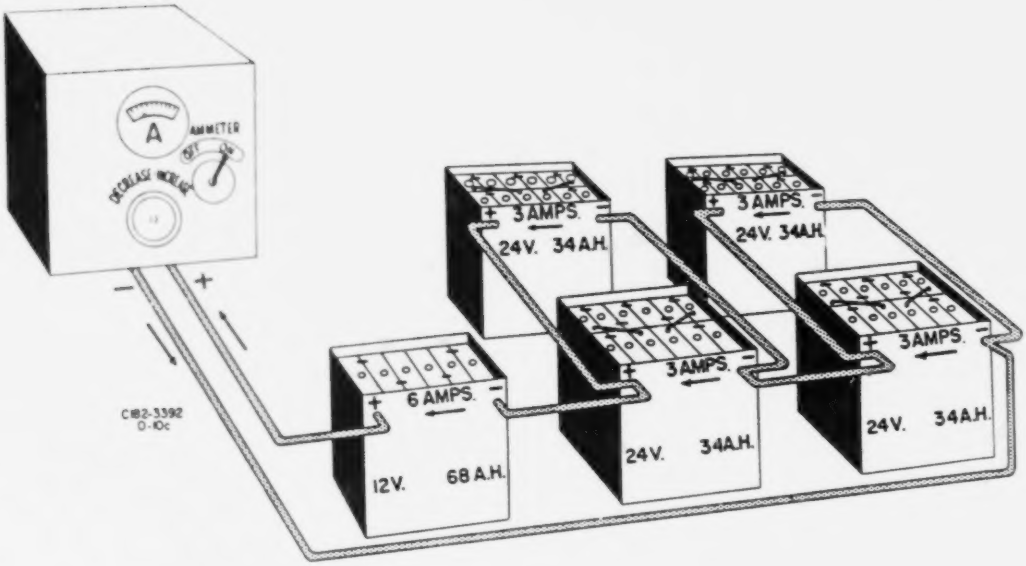
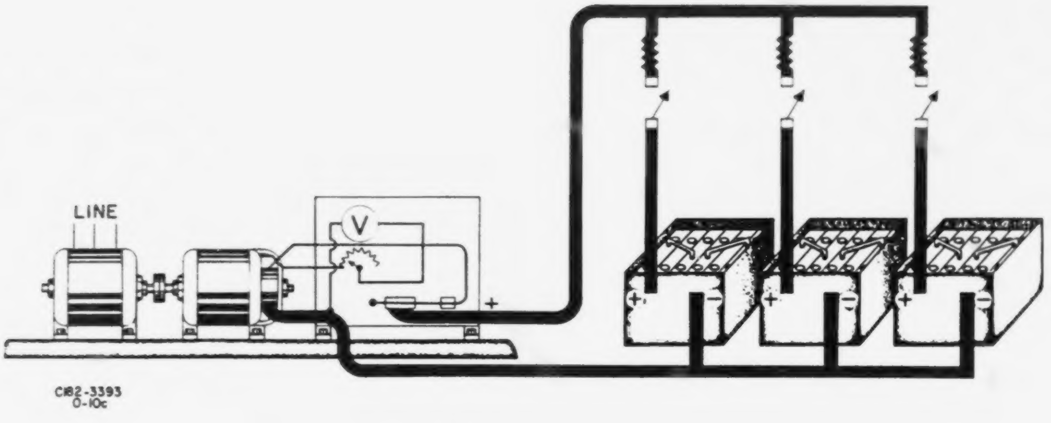

A
AMMETER
OFF ON
DECREASE INCREASE
−
+
3 AMPS.
24V. 34 A.H.
3 AMPS.
24V. 34A.H.
3 AMPS.
24V. 34A.H.
3 AMPS.
24V. 34A.H.
6 AMPS.
12V. 68 A.H.
C182-3392
0-10c

Figure 5-3. Constant-current charging, different capacity in series.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V
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Figure 5-4. Constant-potential charging.

and then connect the series string in parallel with the source.

You must inspect batteries undergoing charge at certain time-intervals. You should take specific gravity readings of the positive-end cell of the batteries first, as this is the last cell to receive a charge. If the positive-end cell gravity reading is up to charge, you should check all the other cells. Take the first specific gravity reading after 4 hours of charging and then every 2 hours. Keep a record of these readings. Then when two successive readings show no increase in the specific gravity, remove the battery from the charging line, as it has reached its maximum state of charge. You must check all readings for temperature corrections. If one or more cells fail to come up, the battery must be condemned.

As a battery charges, gas bubbles rise to the surfaces of the electrolyte. This is a normal condition. But what is happening when the electrolyte appears to be boiling violently? Either you are charging the battery too long or at an excessive rate. What should you do? If the battery is fully charged, remove it.

The temperature of a charging battery, which you check from a thermometer reading of the electrolyte, should not be more than 15° above the surrounding air temperature. If you don't have a thermometer, feel the battery case. If it is uncomfortably warm, it is too hot. Reduce the charging rate and the battery will cool. High temperatures shorten the life of the battery, so check the temperature regularly.

Unless electrolyte is actually lost through spilling or leaking, or acid has been added, the full-charge specific gravity of the electrolyte does not require adjusting (adding electrolyte) during the life of the battery. Electrolyte decreases very little with age. Adjust it only if continued charging results in readings below 1.260 or above 1.310. Before adjusting the specific gravity, charge the battery at the normal rate until the specific gravity shows no further rise with all cells gassing. Do not adjust the specific gravity of a cell if there is no gassing. The reason for this is that if a cell is not gassing, the cell is dead and will not accept a charge. Adjusting the electrolyte at this point would result in a dead cell indicating a charge when, in reality, it is not.

A low specific gravity reading means that you need to replace the electrolyte with a stronger solution. You need to adjust it upward. To do this, withdraw some of the electrolye from the cell and replace it immediately with electrolyte of a higher specific gravity. Continue the charge until all cells have been gassing for one hour, then check the specific gravity of the cells. If it does not check between 1.275 and 1.300, repeat the adjustment.

When the specific gravity reading is higher than 1.300, how do you adjust it downward? Commonsense tells you to reverse the procedure for adjusting the electrolyte upward, and you would be right. Withdraw some electrolyte and replace it with water. Charge the battery at a normal rate until all cells have been gassing for 1 hour. Check the specific gravity. It if is not between 1.275 and 1.300, repeat the adjustment.

Capacity Testing. The capacity test is a bench check used to measure the terminal voltage of a lead-acid battery while it is under load and to determine the battery's internal condition. Before performing the capacity test, fully charge the battery and then overcharge it for 2 hours. After checking to assure that the specific gravity of all cells is correct and within limits, allow the battery to stand for 12 hours.

The capacity tester consists of two battery-test leads that are bridged by an adjustable nichrome resistor, a voltmeter, and a timer. After you have connected the load and voltmeter leads to the battery terminals, adjust the variable resistor to correspond to the capacity of the battery you are testing. As soon as you actuate the battery test switch on the tester, the battery delivers current and the recording timer records the time. Capacity-testing information is listed in a table contained in TO 8D2-1-31. The time, in minutes, that the battery is expected to deliver a certain amount of current (discharge rate) is included in the table. At the end of this time, the voltage must be equal to or above the voltage shown in the End Voltage column of the table. When testing a battery, you must carefully observe the voltmeter and the timer. When the timer reaches the time listed in the Discharge Time column of the table, the voltage should be equal to or above that listed in the End Voltage column. This indicates that the battery has passed the test satisfactorily.

When you have tested the battery, and have found it suitable for further service, tag and mark it CAPACITY TEST OK. A record to indicate that a battery has been capacity tested and the date of the test is stamped on the battery case in a place where it will be plainly visible when the battery is installed in an aircraft. The capacity test is performed every 120 days and each new test date is recorded on the battery directly beneath markings or previous dates. After the battery has been marked, it is recharged and placed into service.

Batteries that do not meet the capacity requirements for aircraft may be used in ground support equipment. A battery that falls just short of minimum capacity requirements and doesn't have any dead cells may be used in ground support equipment. When it does not pass any of the above requirements, it is then condemned. If adequate for ground support equipment, 1-inch block letters FOR AGE USE ONLY are placed on two sides of the battery with yellow acid-resistant paint. These batteries may then be used on testing devices, battery carts, or other support equipment. Batteries once used in nonaircraft applications will NOT be used in aircraft. Before any battery can be condemned, it must fail the capacity test as outlined in its TO.

Exercises (088):

1. Define the constant-current charging method.

2. What determines the charging current in a string of batteries connected in series?

3. Define the constant-potential method of charging batteries.

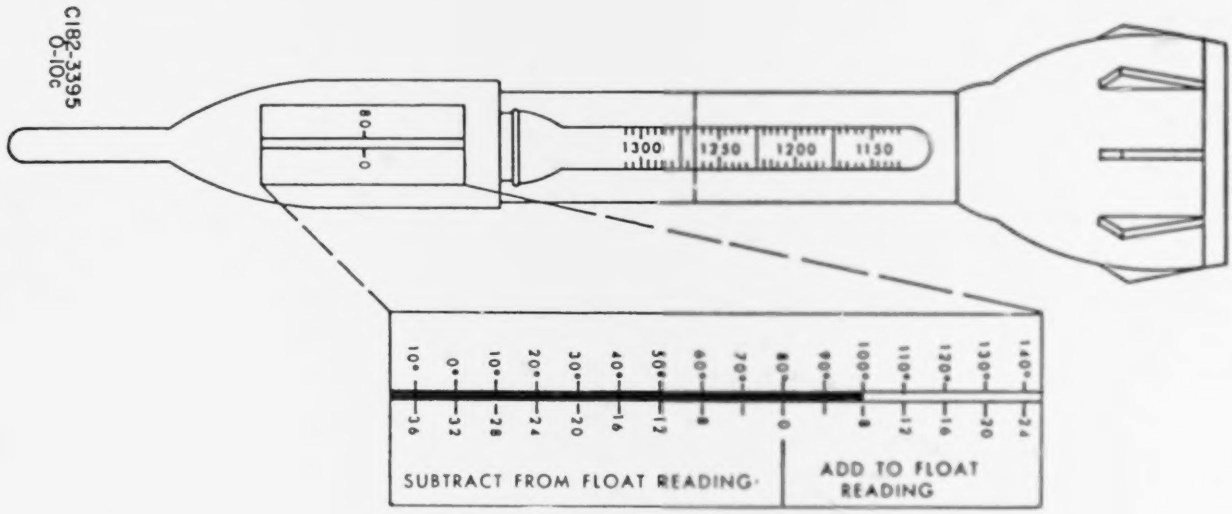

Figure 5-5. Temperature-correcting hydrometer.

4. What can cause the apparent rapid boiling of the electrolyte while charging batteries?

5. What is the purpose of capacity testing a lead-acid battery?

6. How is a lead-acid battery charged prior to performing a capacity test?

7. What happens to a lead-acid battery that fails the capacity test?

5-4. Servicing Batteries

Aircraft lead-acid batteries require a great deal of care and servicing. In order to properly service and care for these batteries, you must know how to use the servicing equipment. Two important items are the hydrometer and the self-leveling syringe. We briefly discuss these in the following section.

089. Cite procedures and standards relating to the use of servicing equipment.

Maintenance and Use of Servicing Equipment. Tools are provided for your use in any job you are required to do. This is also true in the battery shop. Two of the most essential items for servicing batteries are the self-leveling syringe and the hydrometer. Not much can be said as to the maintenance one must give them other than to keep them clean, prevent them from being damaged when not in use, and store them so they will not deteriorate or become damaged. Check the rubber bulb before each use for evidence of cracking due to age and constant use. Also check the glass filler on the hydrometer for cracks or breaks. There is no authorized repair on these items, so you will need to order a new one if they become unserviceable.

Hydrometer. The state of charge of a lead-acid battery is determined by measuring the specific gravity of the electrolyte with a hydrometer. Remember, the electrolyte is a mixture of water and sulphuric acid with a specific gravity of 1.275 to 1.300. As the battery discharges, the sulphuric acid is absorbed from the electrolyte. When the battery is being charged, the charging current forces the sulphuric acid out of the plates and the specific gravity of the electrolyte increases. In reality, the hydrometer measures the amount of sulphuric acid in the electrolyte and indicates the amount as a specific gravity reading. From this reading you can determine the state of the battery's charge.

The type of hydrometer that you will probably be using is the temperature-correcting hydrometer shown in figure 5-5. The depth to which the hydrometer bulb sinks into the electrolyte sample is determined by the density of the electrolyte. The scale value indicated at the level of the electrolyte on the hydrometer is the specific gravity. When a hydrometer is in use, the float should balance upright in the inclosed tube. When the float leans against the sides of the tube, an inaccurate reading results. Extract only enough electrolyte from the cell to cause the float to rise. If too much electrolyte is removed, the float will hit the top and a lower-than-actual specific gravity reading will be indicated. A new fully charged battery should have a specific gravity reading of 1.275 to 1.300. A specific gravity reading between 1.275 and 1.300 indicates a high state of charge;

from 1.240 to 1.275, a medium state of charge; and below 1.240, a low state of charge. Batteries must be recharged if their specific gravity is below 1.240.

You should remember that the concentration of the electrolyte alone is not the cause of the particular state of charge of a cell. Sulphuric acid could be added or the electrolyte entirely replaced in a discharged battery; but the plates would remain in their discharged condition. The specific gravity test is only reliable if nothing has been added to the electrolyte except occasional small amounts of distilled water to replace that water lost due to normal evaporation.

You should make the hydrometer test before adding any water to the electrolyte in a cell. This precaution is necessary because the water is lighter than the electolyte and will tend to float on top of the electrolyte in the cell. Therefore, if you make a hydrometer test immediately after adding water, the hydrometer syringe will suck up a sample which will not give a true indication of the condition of the electrolyte. Appreciable time is required for the water to mix with the electrolyte; to speed up the mixing process, the battery may be discharged and recharged.

TABLE 5-2
TEMPERATURE CORRECTION CHART FOR SPECIFIC GRAVITY TESTER

Electrolyte Temp. F°	Electrolyte Temp. C°	Specific Gravity Correction (Points)	
140	60	24	Add to Reading
130	54	20	
120	49	16	
110	43	12	
100	38	8	
90	32	No correction required	
80	27		
70	21		
60	16	8	Subtract from Reading
50	10	12	
40	4	16	
30	- 1	20	
20	- 7	24	
10	-12	28	
0	-18	32	
-10	-23	36	
-20	-29	40	
-30	-35	44	

CI82-3396
0-10c

Since temperature affects the density of the electrolyte, you must always consider it when you check the specific gravity of the electrolyte. The temperature-correcting hydrometer, as shown in figure 5-5, includes a thermometer that indicates the temperature of the electrolyte at the same time you are checking its density. This permits you to apply an immediate correction to get a corrected specific gravity reading. The correction points are listed in table 5-2.

Look at table 5-2. Note that 80° F (27° C) is used as reference point 0. If the electrolyte temperature is between 65° F (18° C) and 95° F (35° C), no correction need be made because of the small correction between these temperatures. However, the correction should always be made for other temperatures.

What would the specific gravity reading of a battery be if you took a reading and the hydrometer indicated 1.250 and the temperature was 50° F (10° C)? Look at the temperature correction table. For 50° F (10° C), what would we subtract? Twelve points is right. Your original reading of 1.250 minus 12 points now equals 1.238. This tells you that the battery is in a low state of charge. Remember we have already stated that a battery with a specific gravity reading below 1.240 is in a low state of charge.

Before you place a battery on charge, you must do several things to it. The first step is to clean the outside of the case and the top of the battery cells with a small hose and plenty of fresh water. Neutralize any acid on the battery with a solution of bicarbonate of soda. You should remove all corrosion by scraping or brushing the surface clean with a nonmetallic brush. Then remove all traces of acid film from the connections or terminals, using a cloth that has been dampened with a soda solution. After this treatment, cover the metal surfaces with a light film of pure vaseline to protect them from future acid action. Why vaseline? Ordinary greases contain an animal or vegetable fat that is more corrosive than the battery electrolyte, but vaseline does not corrode. Dry the tops of the cells with a sponge to pick up any surplus moisture. Always keep them dry because dampness or dirt permits electric currents to leak over the surface between the terminals.

Remove the vent plug and inspect the electrolyte level. Ordinarily, the only loss in volume of the electrolyte is from the loss of its water. While some water is lost by evaporation, most of the loss is due to the action of the charging current that decomposes the water, forming gases which are given off through the vent plugs. Acid is never lost from the battery by evaporation or decomposition. Therefore, it should never be necessary to add new electrolyte unless some should get outside of the cell through carelessness. If the level of electrolyte is low, add distilled water to bring the level to approximately three-eighths of an inch above the protector on top of the separators. You should use only water which is free from impurities. The presence of impurities in the battery causes local actions that tend to discharge the surrounding area of the plate.

Self-leveling syringe. Add water with a self-leveling syringe as shown in figure 5-6. Draw a supply of water into the rubber bowl of the syringe; insert it into the cell; then inject a little water into the cell by squeezing the rubber ball. When you release the pressure on the ball, the surplus fluid returns to the ball. In order to establish the correct level of electrolyte in the cell, a small hole is drilled through the stem of the syringe. When the fluid level is lowered to the edge of the hole, the return of fluid into the syringe stops and the level of the electrolyte is correct.

Two items that are a must in the battery shop then would be the hydrometer and the syringe. These are not the only two items but definitely two of the most essential. Distilled water, baking soda, rubber gloves, rubber boots, rubber aprons, face shields, emergency shower, eye washers, and a sink are also important. It takes planning to set up an efficient battery shop. No one item can be classed as the most important; rather, it is a combination of all items in the battery shop that will make it operate efficiently. As a final note, proper arrangement of your shop's equipment, good ventilation, and good lighting will make the shop a safer place to work.

Exercises (089):

1. a. What does the hydrometer measure in respect to a lead-acid battery's electrolyte?

   b. How is the measurement taken in "a" above then read?

2. What should be the specific gravity of a fully charged lead-acid cell?

3. When should a hydrometer test of a lead-acid cell be taken?

4. When too much electrolyte is removed for a reading, what effect does this have on the reading?

5. How is the correct level of electrolyte established in a lead-acid cell?

090. Explain safety precautions to follow when servicing lead-acid batteries.

Safety for Lead-Acid Batteries. Forget safety just once in the lead-acid battery shop and you can seriously hurt yourself or your teammate. There are many safety hazards. The greatest hazard is the sulphuric acid used in the electrolyte.

Sulphuric acid can cause painful burns if it contacts your hands or other parts of your body. Get it in your eyes and it can blind you. Whenever you are handling or mixing electrolyte, be very careful; wear goggles or a face shield, a rubber apron, rubber acidproof gloves, and rubber boots. If you should accidentally spill or splash some electrolyte on you, you can neutralize it by flushing that area of your body with large quantities of fresh water or a solution of bicarbonate of soda (baking soda) in water. You should always have a quantity of this solution mixed and available when you are servicing lead-acid batteries. OBTAIN MEDICAL ATTENTION AT ONCE.

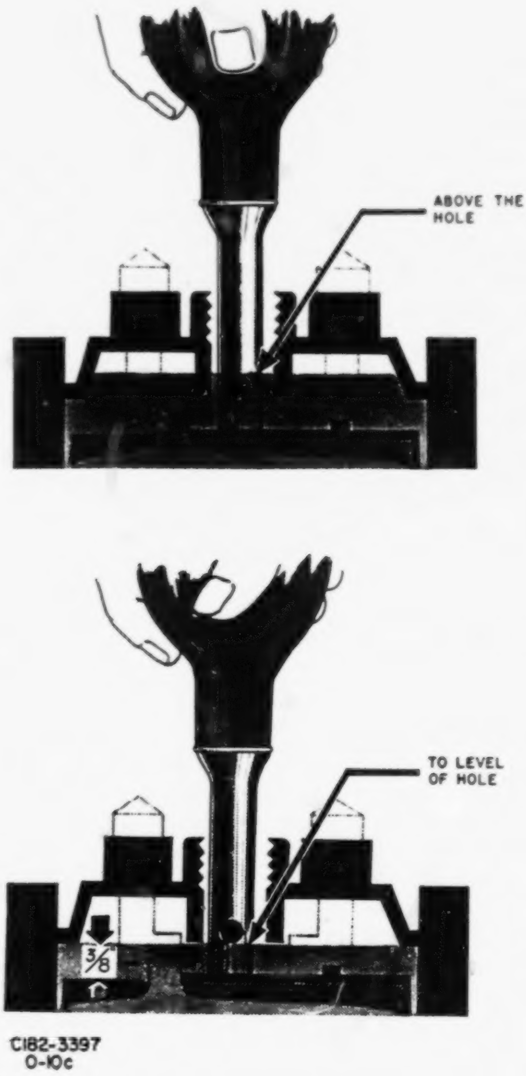

Figure 5-6. Self-leveling syringe.

A fresh water supply can be provided in many forms. It can be just a hose connected to a water tap or, in a large battery shop, a deluge shower and eyewash. If you ever have to use the deluge shower, remember speed is what counts; don't waste time taking off your cloths. The faster you get under the shower and wash away and neutralize the electrolyte, the less you may be burned. If you have a deluge shower and eyewash located in your shop, do you know how they work? Better yet, do they work? Can you get to the deluge shower and eyewash without tripping over batteries or servicing equipment? Can you get to them with your eyes closed? If you answer "No" to any of these questions, a safety hazard exists and needs your attention.

Hydrogen gas is another hazard to safety in the lead-acid battery shop. Produced by the charging batteries, it is a colorless, odorless, highly flammable gas. You'll never know it's there until it's too late. Take every precaution to eliminate sparks in this area. It only takes one spark to ignite hydrogen gas and put you out of a job. Here are a few precautions:

a. Turn off the charging units before connecting or disconnecting a battery to a charger.

b. Don't smoke. Do not allow someone entering the shop to smoke.

c. Remove all jewelry. Getting a ring or watchband shorted across a battery will cause sparks to fly. The battery shop has many safety hazards. It is up to you to recognize them and to take positive, preventive action so that foolish accidents don't hinder your operation.

Exercises (090):

1. Why should a deluge shower and eyewash be installed in a battery shop?

2. When handling or mixing electrolyte, what safety precautions should be observed?

3. What gas is produced when charging batteries? What hazards does it create?

091. Explain safety precautions to follow when servicing nickel-cadmium batteries.

Safety for Nickel-Cadium Batteries. Many of the safety precautions that apply to lead-acid batteries also apply when you service nickel-cadmium batteries. In addition, the electrolyte used in nickel-cadmium batteries contains potassium hydroxide, which is a very strong alkaline. Like sulphuric acid, potassium hydroxide can cause serious burns if it contacts your skin. When handling this electrolyte, you should wear protective clothing, such as an alkaliproof apron, rubber gloves, face mask or goggles, and rubber boots. Sounds like a repeat of the lead-acid battery section, doesn't it?

The following procedures are recommended if you should accidentally swallow Ni-Cad electrolyte or splash it on yourself:

Internal—Take large quantities of water and a weak acid solution such as vinegar, lemon juice, or orange juice, followed by either the white of an egg, olive oil, starch water, mineral oil, or melted butter. OBTAIN MEDICAL ATTENTION AT ONCE.

External—To treat the skin, flush the affected area with large quantities of water. Neutralize with vinegar, lemon juice, or a 5 percent boric acid solution, and flush with water. If you get it in your eyes, flush with clear water or, using an eye cup, wash with a weak solution of boric acid or vinegar and water. Then repeat with clear water. OBTAIN MEDICAL ATTENTION AT ONCE.

As you see, there are many things you can use to neutralize potassium hydroxide. True, you may not have all of these items in your shop, but you should have the boric acid. As in the lead-acid battery shop, you should have running water available, such as a hose, deluge shower, and eyewash. The faster you can dilute any electrolyte splashed on you, the better off you are.

Nickel-cadmium battery shops will be mechanically ventilated to provide 3 to 4 air changes per hour. Adequate ventilation insures the removal of any hydrogen gas generated as a result of charging. Smoking and other ignition sources will be prohibited in the battery shop, because the hydrogen gas generated by nickel-cadmium batteries is explosive. Remember, you should remove all jewelry whenever you work around any electrical equipment, whether in the shop or on the flight line.

What do you think would happen if you accidently got some sulphuric acid electrolyte into a nickel-cadmium battery? This situation has occurred and accidents have resulted. If some sulphuric acid electrolye gets connected to a charging source, they can blow up. Why? Without going into the chemical formulas, we will explain how this happens. When the acid is mixed with the alkaline, they tend to neutralize each other. Theoretically, if this happened, we would end up with water. When the battery is connected to a charging source, the water acts as a short circuit in the battery, thereby resulting in a high current flow through the battery. The high current flow causes excessive heat and the battery explodes. You can prevent accidents like this from happening by:

- Isolating alkaline batteries from lead-acid batteries.
- Not using the same tools on lead-acid batteries that you use on alkaline batteries.

Only you can prevent accidents from happening by knowing the hazards that exist and correcting them before you or someone else gets hurt. You must be safety conscious at all times.

Exercises (091):

1. What kind of protective clothing should you wear when servicing Ni-Cad batteries?

2. What can you use to neutralize Ni-Cad electrolyte on you skin?

3. Why is *smoking* prohibited in the battery shop?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

001 – 1. Planning, scheduling, controlling, and directing the use of all maintenance resources to meet mission requirements of the organization.
001 – 2. AFR 66–1.

002 – 1. Plans and Scheduling and Documentation.
002 – 2. Quality Control.
002 – 3. Insuring that all personnel are highly trained.
002 – 4. Administrative responsibility for the DCM.

003 – 1. (1) Testing, (2) basic military training, (3) classification, and (4) technical school or DDA.
003 – 2. Administrative, general, mechanical, and electronics.
003 – 3. During basic military training.

004 – 1.
  a. Group of positions which require common qualification.
  b. Air Force Specialty Code identifies a technical specialty.
  c. A description of a specialty as found in AFR 39–1.
  d. An AFSC awarded following certification of ability to perform the duties of an AFS at a specified skill level.
  e. The awarded AFSC in which you are most qualified.
  f. The AFSC the Air Force uses to control your assignments.
  g. Identifies the skill level of the position to which you are assigned on the UDL.
004 – 2.
  a. Airman Aircraft Systems Maintenance Career Field.
  b. Aircraft Accessory Systems subdivision.
  c. Five-skill level position (specialist).
  d. Specific specialty, Aircraft Electrical Systems Specialist.

005 – 1. The biggest difference is in the amount of supervision required.
005 – 2.
  (1) b.
  (2) c.
  (3) c.
  (4) a.

006 – 1. The training necessary to provide an individual with the ability to perform selected duties in another related AFSC.
006 – 2. Letters b and d apply.

007 – 1. To determine if the training in the resident school and CDC courses is adequate to meet the needs of field activities.
007 – 2.
  a. Field evaluation visits.
  b. Direct correspondence questionnaires.
  c. CDC trainee questionnaires.
  d. Training Quality Report.
007 – 3. Training Quality Report, AF Form 1284.

008 – 1. The Information Security Program, the Communications Security Program, and the more overall OPSEC Program.
008 – 2.
  a. The Information Security Program. The subject discussed was obviously classified and should not have been discussed at the club.
  b. The Communication Security Program. "Service club employees were within hearing distance. These persons are unauthorized and certainly have no "need to know" classified information; indeed, one or more of the employees could be enemy agents.
  c. The Physical Security Program. Discussing a new type of bomb that was at the base could lead an enemy agent to cause damage to the base bomb dump or an armed aircraft.
  d. The OPSEC Program. Violations of any military security program are violations of the broader OPSEC Program.

009 – 1. Shortcuts and timesavers at the working level.
009 – 2.
  a. Objectives of the operation.
  b. The operation time and location.

010 – 1. a, b, c, and d.

011 – 1. Reveal it only to authorized persons who have a "need to know." This information should not be revealed to unauthorized persons.
011 – 2. Inform the men that this is classified and should not be revealed to unauthorized persons. Reveal it only to authorized persons who have a "need to know."

CHAPTER 2

012 – 1. Standard publications normally are used.
012 – 2. Air Force regulations normally contain directive and policy material and assign responsibilities. Air Force manuals give detailed instructions that tell personnel how to perform their duties.
012 – 3. Air Force pamphlets.
012 – 4. A field publication.
012 – 5. Supplements are filed behind the basic publications or behind the supplement of the next higher headquarters.

013 – 1. *Numbering Publications.*
013 – 2. The two-digit number designates a specific subject; for instance, to locate publications pertaining to military personnel matters, we would want a publication that began with the number 35.
013 – 3. 34–3–3 would be the Air Force pamphlet. This is indicated by its having a third digit.
013 – 4. AFR 0–2.
013 – 5. The supervisor would have read AFR 0–2, and checked the Obsolete Publications section.
013 – 6. Air Force commands.

014 – 1. To change the index date, the file clerk would enter the proper date in red.
014 – 2. That it is needed and on order, and that no current copy is in the file.
014 – 3. If checked out on the 3d of May, it should be returned by the 6th of May.

015 – 1. TOs contain maintenance and operating instructions, identification of parts, and other information on Air Force equipment.
015 – 2. Air Force Logistics Command (AFLC) develops and publishes technical publications.
015 – 3. The Air Force TO system is authorized and explained in AFR 8–2, *Air Force Technical Order System*.
015 – 4. (1) Indexes, (2) technical manuals, (3) time compliance technical orders, (4) methods and procedures technical orders, and (5) abbreviated technical orders.
015 – 5. *Numerical Index and Requirement Tables* is the full title of TO 0–1–01, but is very often referred to as NI&RTs.

016 – 1. Check a, b, c, d, j, k, l, n, o, p.
016 – 2. The –2 indicates that maintenance instructions are in this TO.

017 – 1.
  a. Revisions.
  b. Changes.
  c. Supplements.
  d. Rescissions.
017 – 2. When changed pages total 80 percent or more of the basic TO.
017 – 3. By miniature pointing hands.
017 – 4. Look on the list of effective pages which is on the back of the title page.
017 – 5. They normally are issued when time and circumstances prevent issuing a standard change.
017 – 6. In numerical sequence by date, in front of the basic TO.

018 – 1. Red Xs around the border indicate that it is an immediate action TCTO and that the aircraft should be grounded immediately. The automatic rescission date is 6 months after issue date.
018 – 2. An immediate action TCTO has a rescission date 6 months after the issue date, so the date would be 13 December 1983.
018 – 3. Routine action category II.
018 – 4. Aircraft inspection requirements.
018 – 5. By aircraft subsystems.
018 – 6. The first page of the "task" under "input conditions."
018 – 7. "Warning" means that a violation of the procedures that follow could result in injury or death.

019 – 1. Sequence charts.
019 – 2. Checklist.
019 – 3. policies, methods, and Procedures of a general nature.

020 – 1. Yes. A deficiency report should be submitted. Steps 15 and 16 are reversed and equipment is subject to damage as it is now written.
020 – 2. Air Force Logistics Command (AFLC).
020 – 3. Check with your supervisor first, then contact Quality Control for assistance.

021 – 1. Airmen, officers, and civilians.
021 – 2. No, the ownership remains with the Air Force.
021 – 3. The supervisor made several errors. First by failing to determine the exact number of personnel who needed batteries; second, by ordering approximately four times the number of batteries necessary even if every person need new batteries; third, by not displaying good supply discipline for personnel to follow.

022 – 1. Persons in the Air Force are required to assume responsibility for the equipment they use. Without these responsibilities, Air Force personnel may become wasteful and careless.
022 – 2. The law passed by Congress holds individuals responsible for public property. It is also the authority for AFR 67–10, which explains this law to the Air Force personnel.
022 – 3. The individual who signed for the toolbox and its contents assumes both responsibility and accountability. The Air Force retains ownership of the property.

023 – 1. A wing commander has command responsibility for all equipment assigned to the wing. Wing commanders know that when a maintenance truck is being used to transport personnel to the base exchange, the squadron commander has not accepted full responsibility.
023 – 2. Commander visits may be very often or very seldom; it depends upon the unit. Those that are complying with regulations, manuals, and local directives must be visited less than those units that are not following procedures correctly.
023 – 3. By issuing timely instructions and directives to meet responsibilities.

024 – 1. The supervisor is normally in the best location to exercise direct control over equipment.
024 – 2. When personnel are working directly under the commander.
024 – 3. This regulation deals with responsibility for public property, and also tells about supervisory responsibilities.
024 – 4. When using, issuing, finding, safeguarding, or transporting Air Force property.
024 – 5. Stop and pick up the boxes and contact the supply unit so that the boxes may be returned to supply channels.
024 – 6. Responsibility that must be assumed by an individual who has physical possession of Government property.

025 – 1. The responsible person must pay for the loss.
025 – 2. The supervisor wants to return reparable and serviceable equipment to the supply channels to have it repaired and/or stocked as serviceable condition. Also, this relieves him of the responsibility for safeguarding unserviceable equipment.
025 – 3. By turning the equipment in to supply for reissue she has transferred the responsibility and accountability to the other shop chief as well as tshe property. Had he just transferred the chairs, she would have retained responsibility and accountability.

026 – 1. The mission of the Air Force activity.
026 – 2. Exact quantities are determined by the major commands and by the base equipment management office (EMO).
026 – 3. Number of aircraft assigned, size of workload, type of maintenance performed, number of personnel assigned, and climatic conditions.
026 – 4. Bench stock is a source of expendable items which enables work to be accomplished without interruption due to lack of supplies.
026 – 5. BASO normally resupplies bench stock items.

027 – 1. a. Means for managing assigned equipment resources.
  b. Planning and scheduling maintenance.
  c. Means for validating and initiating corrective actions on maintenance problems.
027 – 2. Through daily and monthly reports.
027 – 3. Configuration status accounting is used to:
  (1) Identify equipment configuration.
  (2) Assure accomplishment of time compliance technical orders.
  (3) Project workload and scheduling requirements.
  (4) Provide mechanized historical records for designated equipment.

028 – 1. 100 percent.
028 – 2. The workcenter supervisor.

029 – 1. AFTO Form 349 and 350.
029 – 2. AFTO Forms 349 and 350.
029 – 3. Five.
029 – 4. The AFTO Form 350.

030 – 1. The following blocks are used for primary entries to document on-equipment work: 1, 2, 3, 6, 7, 9, 17, 18, and 26 and columns A through N.
030 – 2. Yes. The repair action is considered on-equipment maintenance because the component was removed for convenience of repair.
030 – 3. On separate AFTO Forms 349.
030 – 4. No. When two identical components are removed and replaced, the maintenance action can be recorded as one entry on the AFTO Form 349.
030 – 5. Only for transient aircraft and end items of equipment (except engines) for which ID numbers have not been assigned.
030 – 6. AFTO Form 781A.

031 – 1. Job Control.
031 – 2. No. If two workcenters are involved in the maintenance action, two separate AFTO Forms 349 are required.
031 – 3. The entry in block 3, I.D. No./Serial No.
031 – 4. Job Control or the agency preparing the form.
031 – 5. Only when the form is used as a dispatch document.
031 – 6. That the specialist should begin working on this particular job at 0900 hours.
031 – 7. An estimated time for completion.
031 – 8. When the item on which maintenance is being performed does not have a part number.
031 – 9. Block C, Work Unit Code.
031 – 10. This indicates that work on this job stopped on Julian day 013 at 0910 hours.
031 – 11. Enter the senior person's number whether or not this person is the supervisor.
031 – 12. Close out the line entry in the AFTO Form 349. Enter a statement of the required checkout in block 27 of the form.

032 – 1. Most of the information required for the AFTO Form 350 is found in the corresponding titled blocks of the accompanying AFTO Form 349.
032 – 2. You enter the NIIN.
032 – 3. When a demand has been placed on the supply system for a like item as a replacement, the document number is entered in block 13 of the AFTO Form 350.
032 – 4. Block 15, Shop Use Only, is used to document a repair action when a component was replaced.
032 – 5. The agency responsible for returning the item to a serviceable status.

033 – 1. Job control number 0970431 would indicate job number 431 on 7 April.
033 – 2. The four categories of work are:
  (1) Equipment discrepancies.
  (2) TCTO and time change requirements.
  (3) Inspections.
  (4) Support general work other than inspections.
033 – 3. JCNS —0030 and —0031 would be assigned since the discrepancies are unrelated.
033 – 4. Since all items are alike, only one JCN would be used.
033 – 5. Under the time compliance JCN.
033 – 6. Discrepancies discovered during major inspections are recorded under the inspection JCN.
033 – 7. Support-type work that extends into a second day would still be recorded on the original JCN.

034 – 1. To identify Air Force equipment for reporting and control procedures.
034 – 2. The first part of the standard reporting designator code identifies the general type of equipment. The second part identifies the specific type of equipment.

035 – 1. Submit the AFTO Forms 349 to a parent command semimonthly for processing.
035 – 2. The daily production report is used by lower management levels to check for scheduling, actual work accomplished, etc.
035 – 3. The semimonthly and monthly production summaries.
035 – 4. The monthly work order summary is used as the primary source of information for determining the direct labor hours expended and units produced against each work order by each workcenter.
035 – 5. The system and component discrepancy report.

036 – 1. The supervisor may look for an increase of hours in certain coded systems to determine additional training needs.
036 – 2. The analysis section.
036 – 3. AFTO Form 95.

037 – 1. Unscheduled maintenance.
037 – 2. Aircrews, crew chiefs, and other maintenance personnel.
037 – 3. Work such as TCTOs, loading the aircraft with bombs and mission tapes, and washing the aircraft.

038 – 1. DD Form 1574–1.
038 – 2. A green tag or label indicates a component is unserviceable, but it is also reparable.
038 – 3. AFTO Form 350.
038 – 4. The AFTO Form 350.
038 – 5. To determine the status of equipment at a glance.
038 – 6. (1) b.
(2) c.
(3) a.

039 – 1. In a reusable container.
039 – 2. The RPC.
039 – 3. To protect it from damage at all times.
039 – 4. Maintenance assumes the responsibility and accountability when it sign for the paperwork received from supply. Maintenance will retain the responsibility and accountability until RPC signs for the property.
039 – 5. When maintenance requires a serviceable item and none is in stock.
039 – 6. You must have (1) the component, (2) reusable container, (3) AFTO Form 350 tag documented as required, and (4) paperwork for signatures.

040 – 1. Category I report.
040 – 2. Category II report.
040 – 3. Category II report.
040 – 4. Apparent trends in equipment deficiencies should be recorded on a category II report.

041 – 1. To reduce errors caused by someone misinterpretating your writing.
041 – 2. First name initial, complete last name, and rank or grade.
041 – 3. 15/10/4.
041 – 4. Ask, "Will the reader understand?"

042 – 1. They represent, in the opinion of the individual making the entry, that certain conditions exist requiring attention that may affect mechanical condition, fitness for flight or operation, servicing, inspection, and maintenance of that equipment.
042 – 2. Red X, circled red X, red dash, red diagonal, and black last name initial.
042 – 3. Never. Once entered, even in error, it must be cleared properly with an adequate explanation in the Corrective Action block and signed off.
042 – 4. The red X.
042 – 5. The circled red X.
042 – 6. An unknown condition.
042 – 7. The red diagonal.
042 – 8. A black last name initial over a red symbol indicates that the condition has been corrected.
042 – 9. To make important notations instantly apparent.

043 – 1. The crew chief.
043 – 2. Any defect on the aircraft.
043 – 3. At least one block for each discrepancy. You may use more than one block if the explanation is long.
043 – 4. The replacement of time change items before their normal life cycle ends must be underlined in red.
043 – 5. Only after the malfunction is investigated by the best qualified maintenance person.
043 – 6. So that corrective action is taken to fix the problem and also to provide historical data pertaining to the aircraft.

CHAPTER 3

044 – 1. Human error.
044 – 2. By safety training and enforcement of safety rules.
044 – 3. About 98 percent.

045 – 1. Engine intake, engine exhaust, engine turbine plane, and cartridge starter plane.
045 – 2. Due to the possibility of turbine disintegration and the accompanying hazard of high-velocity flying debris.
045 – 3. Normally a red strip around the fuselage indicates the turbine plane of rotation. If not present, consult the applicable technical order for its location.
045 – 4. Its high velocity and high temperature.
045 – 5. Consult the particular aircraft technical order.
045 – 6. The suction effect.
045 – 7. 25 feet to the front and sides and 4 feet aft of the intake lip.
045 – 8. Ear protectors.

046 – 1. By the presence of red streamers attached to the arms device.
046 – 2. Block II of the AFTO Form 781H.
046 – 3. When warranted or directed by the concerned command.

047 – 1. Radar, electronic countermeasure devices, and high-frequency radio transmitter.
047 – 2. A rise in the internal body temperature with resulting damage to vital organs.
047 – 3. Avoid areas where RF energy is being transmitted.
047 – 4. A radiation absorption screen.

048 – 1. The propellers.
048 – 2. In the applicable technical order for the type of helicopter you are assigned to.

049 – 1. The possibility of personnel being caught between the wing trailing edge and the rest of the aircraft if the wing is advertently moved to the full sweep.
049 – 2. Stay clear of wing-sweep area if there is a possibility of the position of the wing being changed. Should necessity require maintenance in the wing-sweep area, insure that a responsible person knows you are working there.

050 – 1. The explosive charges that eject the seat and the canopy.
050 – 2. Immediately after flight and remain installed while the aircraft is on the ground.
050 – 3. Pull the circuit breaker and tag it so no one will reset it.
050 – 4. After you have attended cockpit familiarization training for the aircraft you are required to maintain.

051 – 1. Alpha rays, beta rays, and gamma rays.
051 – 2. Alpha radiation.
051 – 3. Beta radiation.
051 – 4. Gamma rays.
051 – 5. In units or roentgens per hour (R/HR).
051 – 6. They can damage tissues.
051 – 7. A film badge or dosimeter.
051 – 8. During an accident while handling a nuclear weapon; from a crash of an aircraft carrying a nuclear weapon; or, from an aircraft requiring repair which has flown through a contaminated area.
051 – 9. It is colored yellow and has a symbol colored magenta (reddish purple).

052 – 1. (1) c.
(2) b.
(3) a
(4) c.

(5) a.
(6) a.
(7) a.
(8) c
(9) a.
(10) b.
(11) c.
(12) a.
(13) a.
(14) c.
(15) c.
(16) a.
(17) a.
(18) a.
(19) a.
(20) a.
(21) c.

053 – 1. (1) Provide special containers for FOD materials such as wire clippings, unusable bolts, washers, etc.
(2) Always account for personal effects such as pens, pencils, gloves, identification badges, etc.
(3) Maintain a checklist for tools prior to and after each maintenance task.
(4) Use a few minutes each day for an organized general inspection and physical pickup of foreign objects in operational area.
(5) Maintain a continuous cleanup practice when there is construction in or near aircraft flight-line areas.
(6) Notify Quality Control of any signs of cracking or chipping of ramps and runways.
053 – 2. (1) It will help you discover FOD items that could damage an engine and possibly cause loss of life, and (2) it will create FOD awareness in maintenance personnel.

054 – 1. With the same respect as high-voltage circuits.
054 – 2. Its presence cannot be seen, heard, tasted, or smelled.
054 – 3. (1) Enforce safety procedures; (2) know emergency first-aid treatment, including artificial respiration; (3) permit no one to approach without first giving warning of the dangers; (4) stand where all personnel working on the equipment can be seen and the main power switch can be reached, and (5) immediately disconnect power at the first sign of an emergency.
054 – 4. Approved fire-resistant solvents.

055 – 1. The violence with which the muscles contract sometimes "throws" the body from contact with an electrical circuit.
055 – 2. By causing muscle paralysis, which renders the victim helpless.
055 – 3. When skin is broken, charred, or wet with perspiration.
055 – 4. The body paths of current are a vital factor, and any route involving g the heart or brain is extremely dangerous. Placing one hand behind the back reduces the possibility of current passing in one hand, through the heart or respiratory system, and out the other hand.
055 – 5. Electric shock damages nerve tissue which could cause a slow wasting away of muscle that may not become evident for weeks or months.

056 – 1. a. Rope.
b. Flashlight.
c. First aid kit.
d. CPR instructions.
e. Grounding stick.
f. Insulated fuse pullers.
g. Emergency phone numbers.
h. Safety OI (operating instructions).
i. Hook with hardwood handle or wooden cane.
056 – 2. a. Wool blanket.
b. Snakebite kit.
c. Insulating blanket.

057 – 1. These are caused by nature and are called a natural phenomena.
057 – 2. Inattentiveness, excitability, impatience, and stubbornness.
057 – 3. Unsafe acts and conditions.
057 – 4. By basing training, engineering education, and supervision, and enforcement measures on factual evidence, and directing these toward solutions of problems.
057 – 5. To develop a safety consciousness in the individual.
057 – 6. a. Safety meetings should not conflict with normal operating routine.
b. Instruction should meet the individual needs of the group.
c. Visual aids, i.e., mockups, charts, diagrams, and chalkboards should be used to the fullest extent possible.
d. Use all publicity media to keep accident prevention fundamentals fresh in the mind of everyone.
057 – 7. a. Orientation.
b. Supervisors' training.
c. Job training.
d. General training.
057 – 8. Because it creates lasting impressions during initial contact with the individual.
057 – 9. (1) Because they have a working knowledge of accident prevention, and (2) supervisors must have "know how" in order to successfully train personnel in on-the-job safety.
057 – 10. (1) Personal interviews by the supervisor.
(2) Use of 5-minute "standup" talks.

058 – 1. Separate the victim from the circuit.
058 – 2. By using nonconducting material such as a wooden board, rope, or other nonconducting object.
058 – 3. Speed.
058 – 4. Artificial respiration.
058 – 5. Do not stop artificial respiration and closed cardiac massage until advised to do so by a physician.

059 – 1. Good housekeeping.
059 – 2. (1) Do not allow oily rags to accumulate.
(2) Observe the signs in the NO SMOKING areas.
(3) Do not permit flammable fuels to be stored in open containers.
(4) Never deposit cigarettes or matches in wastebaskets.

060 – 1. Fuel, oxygen, and heat.
060 – 2. Wood, trash, paper, and waste.
060 – 3. Type C.

061 – 1. (1) Water extinguisher.
Advantages—Easy to fill and charge and inexpensive.
Disadvantages—Limited use.
(2) Carbon-dioxide extinguisher.
Advantages—Extinguishes fire quickly, leaves no residue, and will not freeze.
Disadvantages(emIs toxic if used in a small closed room.
(3) Dry-powder extinguisher.
Advantages—Extinguishes fire quickly and will not freeze.
Disadvantages—Will leave residue.
061 – 2. Carbon-dioxide or dry-chemical extinguishers.
061 – 3. The pressure would blow the fire to other locations.

CHAPTER 4

062 – 1. By the letter S on the bolthead.
062 – 2. Check for proper diameter, length, and good mechanical fit.
062 – 3. Check to see that the locking insert has not lost its locking friction or has not become brittle.
062 – 4. In situations where it is necessary to prevent corrosion caused by dissimilar metal contacting surfaces.
062 – 5. On aircraft's primary structure, secondary structures, superstructure, accessories where failure might result in damage or danger to aircraft or personnel, where their failure would permit leakage, or on exposed surfaces subject to airflow; neither are they to be used in places where lockwashers would be subjected to corrosive conductions, or where they will be removed frequently.

063 – 1. Self-locking nuts, cotter pins, and safety wire.
063 – 2. The largest size that will fit consistent with the diameter of the cotter pinhole and/or slots in the nut.
063 – 3. Safety wire size .020.
063 – 4. The pigtail should be 1/4 to 1/2 inch in length and bent back to prevent it from injuring personnel.
063 – 5. Approximately 6 to 8 turns per inch.
063 – 6. Not more than 6 inches.

064 – 1. Switches, relays, rheostats, and potentiometers.

064 – 2. To make, break, or change connections in an electrical circuit.

064 – 3. By the maximum amperage and voltage of the circuit in which the switch is to be used.

064 – 4. Single pole means that current can only enter the switch at one point. The throw means the number of circuits each contactor can complete through the switch.

064 – 5. For such purposes as landing-gear position indication, bomb-bay-door position indication, and drive limit switches.

064 – 6. In fire and overheat warning circuits.

064 – 7. To control a large current with a small current.

064 – 8. A rheostat is generally used for basic circuit calibration. A potentiometer is generally used when a variable resistance is needed or when a voltage needs to be divided.

065 – 1. Fuses, current limiters, and circuit breakers.

065 – 2. Slow-blow.

065 – 3. In aircraft circuits that carry heavy currents.

065 – 4. It can be reset and used again.

065 – 5. They are convenient when you find it necessary to isolate (open) the circuit (by manually opening the circuit breaker) for emergency or troubleshooting problems.

065 – 6. Non-trip-free.

065 – 7. According to the maximum current the protected circuit will use and the maximum voltage possible in the circuit without arcing should the fuse "blow."

066 – 1. They should be separated by a cadmium-plated washer.

066 – 2. In such a manner that any movement of the lugs will cause tightening.

066 – 3. Crimp-on type.

066 – 4. A key and keyway.

067 – 1. Copper.

067 – 2. The larger the wire number, the smaller the diameter of the wire.

067 – 3. By the voltage the insulation can withstand, and by the wire's current-carrying ability.

067 – 4. Grommets are used when a wire bundle comes closer than 1/4 inch to the bulkhead. Cable clamps are used for support and separation of wire bundles from combustible fluid or oxygen lines.

067 – 5. When there is a separation of less than 2 inches from a combustible fluid or from fuel lines, a nylon sleeve (nylon tubing) should be used. Use asbestos or fiberglass wrap in hot areas. Use plastic tubing in wet areas. Use flexible tubing or metal conduit in open areas subject to excessive wind and/or flying objects.

068 – 1. A distance of 12 inches.

068 – 2. To identify temporary ties.

068 – 3. Flat-type tape will not cut into wire bundles during vibration.

069 – 1. The replaced hardware must be of the same material as that removed.

069 – 2. No more than 0.1 ohm.

069 – 3. The electrical connection made from a conducting object to the primary structure for a low resistance return path for current.

069 – 4. Any fixed union existing between two metallic objects and permitting good electrical conductivity between them.

070 – 1. They are heated, which causes them to shrink.

070 – 2. Thermofit material.

070 – 3. Up to 50 percent.

070 – 4. Heat gun.

071 – 1. To use the wire-marking machine, heat the holder and apply pressure to the foil on the wire in the wire guide; this transfers the number to the wire.

071 – 2. The crimping tool.

071 – 3. Hand stripper and common jackknife.

072 – 1. A 1/4-inch drive breakaway torque wrench that could be set at 25 inch-pounds.

072 – 2. Turn the handle counterclockwise.

072 – 3. At least once every 60 days.

072 – 4. The lowest usable setting.

073 – 1. It must be large enough for the job, and the blade should fit the screw slot snugly.

073 – 2. Remove as little of the tip as possible and do not overheat the metal.

073 – 3. An offset screwdriver.

073 – 4. A cross-point screwdriver.

074 – 1. (1) b.
  (2) d.
  (3) a.
  (4) e.
  (5) c.
  (6) d.
  (7) e.
  (8) a.
  (9) d.

075 – 1. To help prevent injury to your hand.

075 – 2. An adjustable-jaw wrench.

075 – 3. a. No.
  b. Yes.
  c. No.
  d. No.
  e. Yes.
  f. Yes.
  g. No.

076 – 1. a. The categories are hard and soft.
  b. Hard solder contains alloys of silver; whereas, soft solder contains alloys of tin and lead.

076 – 2. Soft solder, in wire form, and filled with rosin flux.

076 – 3. Acid will corrode the wire and destroy the connection; also, it will produce "noise" voltages in electronic circuitry.

077 – 1. a. The induction-type soldering gun.
  b. It has the ability to rapidly provide sufficient heat for soldering normal-sized wire.

077 – 2. a. A low-wattage pencil-type iron.
  b. To avoid overheating and damaging transistors and other semiconductor devices.

077 – 3. By filing the tip with a flat, fine, single-cut file.

077 – 4. The soldering tip should be coated with solder (tinned).

077 – 5. Thermal-shock cleaning; i.e., wiping the iron's tip with a cool, moist sponge.

078 – 1. Because the solder may splatter.

078 – 2. Tinning keeps the wire strands from unraveling.

078 – 3. A weak joint could develop.

078 – 4. It probably had too much heat applied.

079 – 1. a. Heat sink.
  b. Between the component or wire and the solder joint.
  c. It is a material or device attached to the component being soldered, and it absorbs some of the heat being applied.

079 – 2. a. The insulation around the wire may melt and expose the bare wire.
  b. By replacing or taping the wire.

079 – 3. You are simultaneously melting the solder and straightening the leads and small wires bent against the terminal board.

079 – 4. This space allows room for air circulation, and it also provides sufficient space for use of a heat sink on the leads.

079 – 5. Apply the solder to the point of the soldering iron contact—not to the soldering iron.

080 – 1. The primary purpose of the inspection system is to locate and repair equipment prior to total system failure.

080 – 2. The Air Force has developed the –6 series TOs to outline inspection requirements.

081 – 1. To prevent aircraft disablement and flight-schedule interruption by finding and repairing faults during scheduled aircraft downtime.

081 – 2. TO 8–1–1.

081 – 3. Parallel to combustible fluid or oxygen lines, and separated from them by at least 6 inches.

081 – 4. Not more than 24 inches.

082 – 1. To reduce FOD.

082 – 2. Strict accountability and easy tool inventory.
082 – 3. By a number or color code.
082 – 4. At the start and finish of each job and quarterly.

CHAPTER 5

083 – 1. Always pour the acid into the water.
083 – 2. Electrolyte-proof goggles or full faceshields, rubber gloves, rubber aprons, and acid-resistant safety shoes or rubber knee-length boots.
083 – 3. Insure that battery shop personnel are thoroughly trained and indoctrinated in safe operating procedure.

084 – 1. Sulphuric acid and water.
084 – 2. They are called *separators* and are used to electrically insulate the plates from each other so they cannot touch.
084 – 3. By using nonleakable vent caps which act as vents when the battery is right-side-up and as valves when the aircraft is upside-down.
084 – 4. In ampere-hours.

085 – 1. Nickel oxide on the positive plate and metallic cadmium on the negative.
085 – 2. 1.25 volts.
085 – 3. Either nylon and cellophane or Parmion.
085 – 4. Between 2 to 10 psi.
085 – 5. 30 percent potassium hydroxide (KOH) in distilled water.
085 – 6. An uncontrollable rise in battery temperature that can destroy the battery.

086 – 1. Constant-current method.
086 – 2. A capacity check.
086 – 3. When the cell voltage of each cell is at zero volts.
086 – 4. Three.
086 – 5.
086 – 6. One-eighth inch.

087 – 1. By natural convection air cooling.
087 – 2. At least once every week.
087 – 3. Damaged or deteriorated insulation, loose terminals, and broken wires.

088 – 1. Current is maintained at a predetermined value throughout the entire period of charge.
088 – 2. The ampere-hour capacity of the smallest capacity battery in the string.
088 – 3. The voltage is maintained at a predetermined valve throughout the entire period of charge.
088 – 4. Boiling will occur when the battery is overcharged or has been charging at an excessive rate.
088 – 5. To determine the battery's terminal voltage and state of wear.
088 – 6. The battery is brought to a full charge and then overcharged for 2 additional hours.
088 – 7. It is either condemned or painted with 1-inch block letters in acid-resistant yellow paint FOR AGE USE ONLY.

089 – 1. a. It measures the amount of sulphuric acid in the electrolyte.
    b. As a specific gravity reading.
089 – 2. Approximately 1.275.
089 – 3. Before adding water to the cell.
089 – 4. A lower-than-actual specific gravity reading will be indicated.
089 – 5. A small hole is drilled in the stem of a syringe. When the fluid level is lowered to the edge of the hole and the syringe is bottomed on the plate, the level will be correct.

090 – 1. To be used in case electrolyte is accidently splashed or spilled on you.
090 – 2. You should wear goggles or a face shield, rubber apron, rubber gloves, and rubber boots and know to reach fresh water.
090 – 3. Hydrogen gas. It is highly flammable and can explode.

091 – 1. Protective apron, rubber gloves, face mask or goggles, and rubber boots.
091 – 2. Vinegar, lemon juice, or a 5 percent boric acid solution will help neutralize Ni-Cad electrolyte.
091 – 3. Because hydrogen gas is very explosive.

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CDC 42350

AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST

(AFSC 42350)

Volume 2

Electrical Systems and Test Equipment

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Preface

THE SECOND volume of CDC 42350 deals with aircraft electrical systems and the test equipment you use to maintain these systems. This volume is divided into five chapters.

Chapter 1 covers electrical fundamentals that you will need to know. These fundamentals will assist you in troublshooting various electrical systems and components.

Chapter 2 will help you understand how electricians should use meters and test equipment.

Chapters 3 and 4 explain DC and AC generator systems, respectively. Generators, system components, and the different generator systems that power aircraft are covered in detail.

In Chapter 5 you will study some other electrical power systems used on many aircraft and finish with a study of motors.

Foldout 1 is bound in the back of this volume.

Code numbers appearing on figures are for preparing agency identification only.

The inclusion of names of any specific commercial product, commodity, or service in this publication is for information purposes only and does not imply indorsement by the Air Force.

This volume is valued at 27 hours (9 points).

Material in this volume is technically accurate, adequate, and current as of February 1983.

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Electrical and Electronic Circuits and Diagrams

DURING YOUR CAREER in the aircraft electrical systems career field, you will be required to maintain many electrical and electronic systems. A thorough understanding of the fundamentals of electricity will permit you to do your work with ease. The learning objectives in this chapter are designed to help you become proficient in electrical/electronic fundamentals.

1-1. DC Theory and Circuits

In this section we discuss electron theory and direct current fundamentals. We use Ohm's law and Kirchhoff's laws in circuit analysis. We also cover magnetism and motor principles.

200. Describe the parts of an atom and explain voltage, current, and resistance.

Structure of an Atom. An atom consists of (1) neutrons (electrically neutral), (2) protons (positively charged), and (3) electrons (negatively charged). Protons and neutrons form the nucleus (core of the atom), whereas, electrons orbit the nucleus in much the same manner as planets orbit the sun. In the study of atoms, we are primarily interested in the outer orbit of electrons. The atom of one element differs from an atom of another element only in the number and arrangement of neutrons, protons, and electrons.

Under normal conditions, each atom contains an equal number of protons and electrons. Therefore, they are referred to as *balanced* or *stable* atoms. Electrons are kept in orbit because of their attraction to the protons in the nucleus. The atom itself tries to keep the same number of protons and electrons. However, when acted on by an outside force, electrons move from their orbits and cause the atom to become unbalanced. In this state, the protons outnumber the electrons, and the atom takes on a new positive charge (positive ion). The addition of an electron to a stable atom results in just the opposite effect; it has a negative charge (negative ion).

Forces that cause electrons to be released from their outer orbit are:

- Friction.
- Heat (vacuum tube).
- Light (photoelectric cell).
- Pressure (piezoelectric effect, such as radio crystals).
- Chemical (batteries).
- A changing magnetic field (such as generators, alternators, or transformers).

When an atom becomes unbalanced, it will try to attract another electron to restore its original balanced condition. A common law of electricity states that like charges repel and unlike charges attract. In other words, electrons will repel other electrons, but will attract protons. Remember, we have only been talking about one atom. There are thousands within a single piece of substance. Therefore, when detached electrons (free electrons) are close to a positively charged atom of the same substance or a neighboring atom of some other substance, they will try to attach themselves to that substance. This enables normally neutral substances to acquire either a positive or negative charge.

All matter is composed of atoms which are made up of electrons, protons, and neutrons. These particles in proper combinations can produce electrical charges. However, this does not mean that all materials are useful for the generation or transmission of electricity in a practical sense. We will discuss some materials used in electrical circuits.

Insulators. Insulators are substances that have tightly bound orbiting electrons. These electrons are held firmly in place by the nucleus. Substances such as wood, plastic, rubber, and glass are good examples of insulators.

Conductors. Some substances have electrons that are loosely bound to the nucleus and can be easily freed by applying a suitable force. Substances of this type are called *conductors*. Platinum, gold, silver, and copper are all good conductors.

Semiconductors. Semiconductors are used in solid-state devices; their resistance and conductivity fall between insulators and conductors. Germanium and silicon are materials most commonly used as semiconductors.

A good conductor offers little opposition to electron flow, whereas insulators offer a great deal of opposition. Semiconductors are not good conductors, but are better conductors than insulators. Actually, there is no such thing as a perfect conductor. A substance is either a good conductor or a poor conductor; a good insulator or a poor insulator.

Electromotive Force. Electron movement will occur anytime a difference in electrical potential exists between two points of a conductor. An electrical potential (pressure) exists whenever there are more electrons at one point than at the other. The greater the difference in the number of electrons, the greater the electrical pressure and amount of electron flow.

Remember, earlier, when we discussed the forces that caused electrons to be released from their outer orbits. Among those factors listed, one was chemical (batteries).

As an experiment, let's connect a conductor (copper wire) between the negative and positive posts of the battery. As soon as these connections are made, a circuit is completed, and the difference in electrical potential causes electrons to move through the conductor. Electrons move from positive to negative inside the battery and from negative to positive in the conductor. As an electron leaves the negative terminal of the battery, it immediately repels, or causes an electron in the conductor to leave its orbit. This free electron repels another electron, and it leaves its orbit, then another, etc. An instantaneous chain reaction takes place throughout the entire conductor. The electrical pressure which causes electrons to flow through the conductor is called *electromotive force* (EMF). You can consider EMF as an "electron moving force." Another term used to describe this pressure or force is *potential difference*. Electromotive force and potential difference are two ways of saying the same thing. They both mean electrical pressure.

The unit of measurement of electrical pressure is the volt. Therefore, we refer to an electrical circuit as having so much voltage. The symbol used for the volt is "V", and symbol used for EMF is "E."

Electrical Current. Electrical current is the movement of electrons through a conductor. The unit of measurement for current is the ampere. One ampere of current is the flow (across a certain point) of one coulomb of electrons in one second. When we speak of amperes, we are referring to the intensity of the current flow in a conductor. The standard symbol for current is "I."

Electrical Resistance. Previously, we stated that there was no such thing as a perfect conductor or insulator. This means that all conductors and insulators offer, at least, some opposition to current flow.

From our previous study of matter, we learned that material differ in their ability to transfer electrons. All substances have different electron arrangements, hence different substances offer different amounts of resistance to current flow. A length of copper wire offers less resistance to current flow than an iron wire of the same dimensions. The type of material used is one of the factors that determine the amount of resistance in a conductor. Temperature and size are the other factors. For most materials, the hotter the material, the more resistance it offers. The colder the material, the less resistance. The amount of resistance change in relation to temperature change is known as temperature coefficient. If an increase in temperature causes the resistance to increase, the material has a positive temperature coefficient. A material has a negative coefficient when an increase in temperature causes its resistance to decrease.

You can see the need for a unit of measurement for resistance that will allow numerical values to express the amount of resistance present. This unit of measurement is the ohm. The symbol used to represent the ohm is Greek letter omega Ω. The letter "R" is used to designate resistance. There is a definite relationship of resistance, current, and electromotive force. By the use of different resistors, we can control current flow. The other factor controlling current flow is the voltage applied, or difference in potential.

Exercises (200):

1. Describe the three particles that make up the structure of the atom.

2. What electrical charge does an atom have under normal conditions?

3. Name three forces that will cause electrons to be released from their orbit.

4. What electrical term is used to identify material with loosely bound electrons?

5. Describe electrical pressure, and state its unit of measurement.

6. Give three examples of materials that make good insulators and explain why.

7. What factors determine the amount of resistance of a material?

8. What is the unit of measurement for resistance?

201. Analyze electrical problems using Ohm's law, Kirchhoff's law, and electrical formulas.

Ohm's Law. While experimenting with electricity in the early 1800s, a German physicist, George Simon Ohm, discovered a definite relationship between voltage, current, and resistance. During his experiments, Ohm found that:

- When voltage increased—current increased.
- When voltage decreased—current decreased.
- When resistance increased—current decreased.
- When resistance decreased—current increased.

From these findings, Ohm concluded that current in any electrical circuit is directly proportional to voltage, and inversely proportional to resistance. These discoveries led to more experiments and, eventually, became one of the fundamental laws used in analyzing electrical circuits. The law became known as Ohm's law and, in modern language, stated: "The current (amperes) in a circuit is equal to the voltage (volts), divided by the resistance (ohms)."

The same law written as an equation is:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

or

$$\text{Current} = \frac{\text{Volts}}{\text{Ohms}}$$

A common method of writing the law is by formula; for example,

$$I = \frac{E}{R}$$

Perhaps you are wondering just how these letters came to represent current, voltage, and resistance. When measuring current, you measure the charged particles (electrons) passing a point in a circuit in a given unit of time (the intensity of the particles). Therefore, the letter "I" is associated with current because it is the first letter in the word intensity. The letter "E," which represents voltage, is the first letter in the words, electromotive force. The "R," for resistance, is self-explanatory. It is important that you remember that Ohm's law applies to any part of a circuit as well as the entire circuit. Basic Ohm's law formulas are the simplest and most commonly used to find an unknown value (voltage, current, or resistance), when the values of the other two qualities are known.

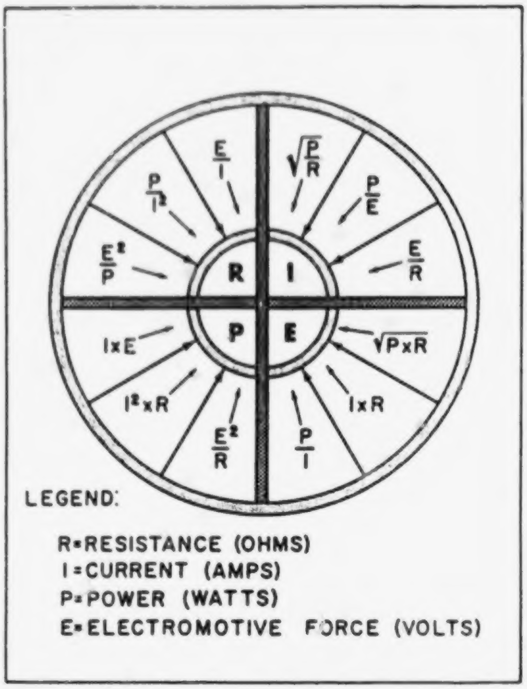

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Figure 1-1. Magic wheel.

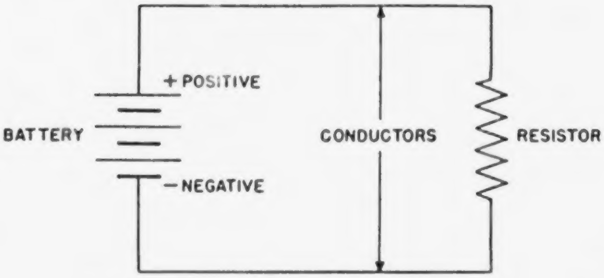

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Figure 1-2. Simple circuit.

Sometimes a memory aid is used to make the Ohm's law formulas more easily remembered. For those who are skilled in the use of algerbra, it is a simple matter to work formula problems. But, for others, it may be easier to use the simplified magic wheel pictured in figure 1-1.

If you know any two of the four measurable properties of electricity, you can use the magic wheel to solve for an unknown third. The large black letters in the center of the wheel stand for the unknown properties. Outward in the same quadrant (one-fourth circle), there are three formulas with arrows pointing toward the selected unknown. Select the formula that contains the letters standing for the two known properties. Note the inclusion of power (P) in the basic voltage, current, and resistance relationships of Ohm's law.

Power is measured in watts. One watt is the power equivalent of one volt, times one ampere. An example of its use is: A 6-watt light bulb draws 1 ampere in a 6-volt circuit. The inclusion of power is sound in that the basic function of electricity is to transfer energy, which is the ability to develop power (or work).

Now that you know how to find the correct formula, let's work on an actual problem. Assume that the battery, shown in figure 1-2, is 6 volts and the resistance is 3 ohms. Using the magic wheel, determine the correct formula to find the current of the circuit. The formula you should use is

$$I = \frac{E}{R} (I = E \text{ divided by } R).$$

Therefore,

$$I = \frac{6}{3} = 2 \text{ amperes.}$$

Using the same diagram, let's assume that the battery is 12 volts and the current is 2 amperes. What formula do you use, and what is the resistance? The correct formula is:

$$R = \frac{E}{I} \text{ or } R = \frac{12}{2} (12 \text{ divided by } 2) = 6 \text{ ohms.}$$

So the resistance in the circuit is 6 ohms.

Series Circuits. A series circuit is the most simple circuit. In a series circuit there is only one path for current to flow, and electrical devices are connected end to end. The circuit shown in figure 1-2 is a simple series circuit. Current flows from the negative terminal of the battery, through the resistor, and back to the positive side of the battery.

Voltage in a series circuit. Around 1850 a German physicist, Gustav Kirchhoff, elaborated on Ohm's law, and developed his laws concerning voltage, current, and resistance. In simple everyday language, Kirchhoff's voltage law states that in any closed circuit, the applied voltage is equal to the sum of the voltage drops around the circuit. In other words, by adding the voltage drops across each resistor, we can determine the voltage of the source, or battery.

To determine the amount of voltage drop across any one resistor, use the Ohm's law formula ($E = I \times R$) for that part of the circuit. Voltage drop is determined by multiplying the current (I) through the resistor by the resistance of the resistor (R). Because we are dealing with current and resistance, voltage drop may also be referred to as IR drop.

Refer to figure 1-3, and let's figure the voltage drop across each resistor. An important point to remember is that when you have more than one resistor in a circuit, the larger resistor has the largest voltage drop. In our sample circuit, we know that the source (battery) voltage is 12 volts. The formula tells us that the voltage drop across resistor R1 and R adds up to 12 volts (the applied voltage).

By using Ohm's law, we can find the exact voltage drop across each resistor. First, however, you should know that the amperage of the circuit is 2 amps. How we arrive at this figure, we will discuss in a moment. With this information, and the formula for figuring voltage drops ($I \times R$), we can figure the voltage drop across R_1 (2-ohm resistor). We know that $I = 2$ amps and $R_1 = 2$ ohms, therefore, $2 \times 2 = 4$ volts dropped. Since there are only two resistors, R_2 must drop the remainder or 8 volts. Remember, the voltage drops must equal (12 volts) the applied voltage. Let's check to see if R_2 does actually drop the remaining 8 volts. $I = 2$ amps $\times$ $R_2 = 4$ ohms ($2 \times 4 = 8$).

Current in a series circuit. Kirchhoff's current law is the sum of the current at any junction is zero. You have no doubt, long been aware of the meaning of this law. In simple language it states: "In a circuit, the same amount of current flowing from a junction returns to that junction." If ammeters are connected at several points in a series circuit, they show how much current is flowing at various points in the circuit. All the ammeters read the same amount of current. This is an important point to remember about a series circuit—current is the same at all points through the circuit. This may be expressed as $I_t = I_1 = I_3$. Use the following formula to find the current in a series circuit.

$$I = \frac{E \text{ (applied voltage)}}{R_t \text{ (sum of all the resistances)}}$$

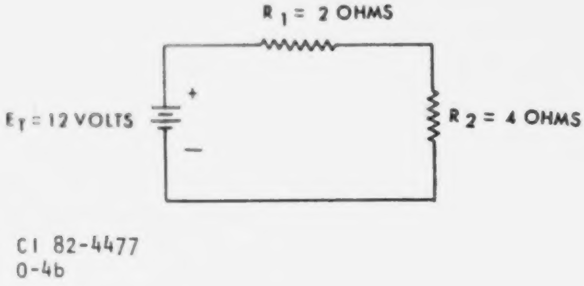

Figure 1-3. Series circuit.

Now, let's explain how we got 2 amps as the circuit current in the previous v example. Refer again to figure 1-3. By adding the 2-ohm and the 4-ohm resistances, we have a total resistance of 6 ohms. The formula tells us to divide the applied voltage 12 by the total resistance 6. Therefore, the circuit current equals 2 amperes.

Total resistance in a series circuit. In a series circuit, the total resistance is the sum of the individual resistances in the circuit. Expressed as a formula: $R_t = R_1 = R_2 + R_3$.

Did you notice as we explained the formula for voltage, current, and resistance that the total voltage is the sum of the voltage drops across the individual resistors? The current remained the same throughout the circuit. The total resistance is the sum of the individual resistors. These facts can be used in remembering what happens to voltage, current, and resistance in a series circuit.

Exercises (201):

1. If a circuit contains 5 ohms of resistance and 50 volts are applied, what will the current flow be?

2. What is the voltage of a circuit that has 3 amperes of current flow and 4 ohms of resistance?

3. Ohm found that when voltage was decreased, current ____________, and when resistance increased, current ____________.

4. What is the power of a circuit that has 2 amperes of current flow and 5 ohms of resistance?

202. Analyze parallel and series-parallel circuits and solve the unknown values of selected parallel and series-parallel circuit problems.

Parallel Circuits. In addition to the series circuit, there is another type of basic circuit. It is known as a parallel circuit because it provides more than one path for current to flow. These separate paths are generally referred to as the "branches" or "legs" of the parallel circuit.

The introduction of additional paths for current flow results in a different set of rules for voltage, current, and resistance. Note the difference in the circuit, as shown in figure 1-4.

Voltage. In a parallel circuit, the applied voltage is the same as the voltage drop across each element (the same voltage is applied across all legs of the circuit). Therefore, for a parallel circuit:

$$E_t = E_1 = E_2 + E_3, \text{etc.}$$

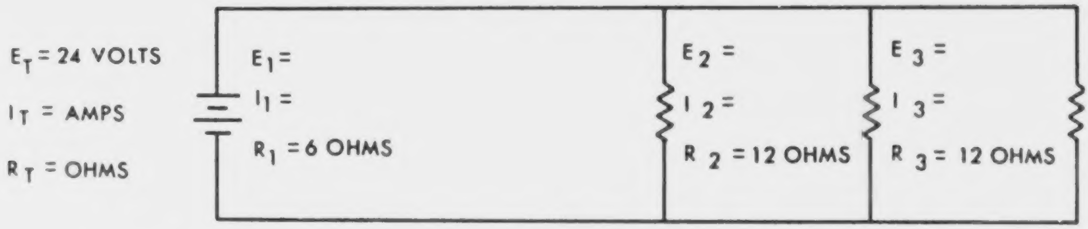

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Figure 1–4. Parallel circuit.

Current. The total current in a parallel circuit is equal to the sum of the current flowing in the individual legs. Thus, for any parallel circuit:

$$I_t = I_1 = I_2 + I_3, \text{etc.}$$

Resistance. In a parallel circuit, the total resistance is always less than the smallest resistance in the circuit. One method of determining the total resistance in a parallel circuit is by an indirect method. First, let's refer to figure 1-4 and find the total current of the circuit. If two values are known, the third value is found by using Ohm's law. We know the voltage in each leg is 24 volts (as explained by the voltage law). We also know the value of each resistor; therefore, let's find the current (amperage) through each resistor. Then we will add up the current values to show total current in the circuit. To figure current of the first resistor (R_1) using Ohm's law, you will be able to come up with 4 amps of current. By adding the current of each resistor, we have a total current of 8 amps. Now, all we have to do is divide the applied voltage by this sum. Thus:

$$R_t = \frac{E}{I} = \frac{24}{8} = 3 \text{ ohms}$$

Another method of determining the total resistance of this circuit is:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ or } \frac{1}{R_t} = \frac{1}{6} + \frac{1}{12} + \frac{1}{12}$$

$$\frac{1}{R_t} = \frac{4}{12} \text{ or } R_t = 3 \text{ ohms}$$

When all resistors are of equal value—example, 9 ohms—use formula:

$$R_t = \frac{\text{value of one resistor}}{\text{number of resistors}} = \frac{9}{3} = 3 \text{ ohms}$$

In conclusion, the following observations should be made concerning parallel circuit operation. The addition of more resistors in a parallel v circuit decreases the total circuit resistance. This is true regardless of how large or how small the resistors are. You must understand that this decrease in total resistance results in an increase of total current, if voltage remains the same. Therefore, if voltage remains the same, the total current can be increased by adding more parallel circuits.

Series-Parallel Circuit. Series-parallel circuits are those which have parallel resistances connected in series with other resistances. Any one of the parallel branches can also contain two or more resistances in series. Problems concerning series-parallel circuits are solved by application of the rules already given for series and parallel circuits. To do this, the series-parallel circuit is first reduced to an equivalent series circuit. This procedure is demonstrated by using the circuit shown in figure 1-5.

Referring to the circuit, notice two 12-ohm resistors connected in parallel. This combination of resistors is in series with resistor R_3. The first step in solving the total resistance is to find the combined resistance value of resistors R_1 and R_2. Using the rule for resistors in parallel, you can determine the parallel section's resistance to be 6 ohms.

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{12 \times 12}{12 + 12} = \frac{144}{24} = 6$$

$$R_t = \frac{12}{2} = 6 \text{ ohms}$$

This simply means that there is really 6 ohms of resistance in the parallel portion of the circuit. This resistance, you will notice, is in v series with resistor R_3. Adding the 6 ohms total resistance of R_1 and R_2 to the 6 ohms of resistor R_3 gives the total resistance of the entire circuit (12 ohms). By adding, you are following the rule for finding total resistance in a series circuit. Now you can determine that the total current is 2 amperes.

All of the current passes through resistor R_3 and divides at the parallel section. One ampere of current flows through resistor R_1, and one ampere flows through R_2. From the junction, the current returning toward the positive terminal of the battery is once again 2 amperes.

These current values are checked by applying Ohm's law to the parts of this circuit. It is determined that the voltage loss across resistor R_3 is 12 volts. The remaining 12 volts applied to 12 ohms in each leg of the parallel section results in 1 ampere of currrent flow. You see here the importance

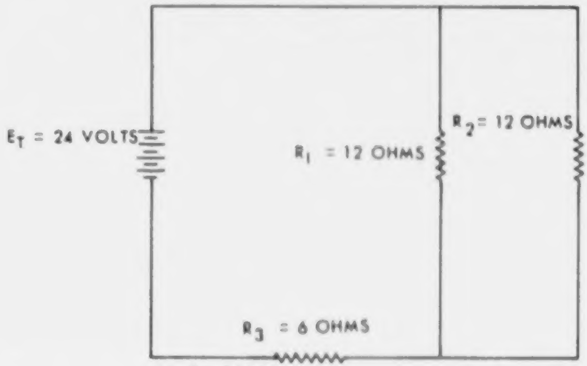

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Figure 1–5. Series-parallel circuit.

of completely understanding the rules for both series and parallel circuits in solving circuit problems of this type.

Exercises (202):

1. What is the total amperage of a parallel circuit containing a 12-volt power source, and three resistors with values of 12, 4, and 6 ohms?

2. If voltage remains the same, what is the effect on total circuit resistance if more resistors are added to a parallel circuit?

3. A parallel circuit has ____________ ____________ ____________ path for current flow.

4. In a parallel circuit, ____________ ____________ remains the same in all legs of the circuit.

5. Define a series-parallel circuit.

6. Find the total resistance of a series-parallel circuit having 2 parallel resistors (20 ohms each) in series with a 30-ohm resistor.

203. Name the types of magnets, and define the terms used to describe them.

Natural and Artificial Magnets. Magnetic lode stones, such as those found by the ancient Greeks, are considered to be natural magnets. These stones have the ability to attract small pieces of iron in a manner similar to the magnets that are common today. However, the magnetic properties of the stones were products of nature and not the result of the efforts of man. The Greeks called these substances "magnetic." However, such magnets no longer have any practical use, for it is now possible to easily produce more powerful artificial magnets. These are usually chemical alloys of magnetic materials and are referred to as artificial magnets.

Artificial magnets are usually classified as *permanent* or *temporary*, depending on their ability to retain their magnetic properties after the magnetizing force has been removed. Magnets made from substances such as hardened steel, and certain alloys retain a great deal of their magnetism. Thus, they are called *permanent magnets*. These materials are relatively difficult to magnetize because of the opposition offered to the magnetic lines of force as the lines of force try to distribute themselves throughout the material. This opposition the material offers to the magnetic lines of force is called *reluctance*. All permanent magnets are produced from materials having a high reluctance.

A material with a low reluctance, such as soft iron or annealed silicon, is relatively easy to magnetize, but will retain only a small part of its magnetism once the magnetizing force is removed. Materials of this type that easily lose most of their magnetic strength are called *temporary magnets*. The amount of magnetism remaining in a temporary magnet is referred to as *residual* magnetism. The ability of a material to retain an amount of residual magnetism is called the *retentivity* of the material.

Magnets are described also in terms of the permeability of their materials, or the ease with which magnetic lines of force distribute themselves throughout the material. A permanent magnet is produced from a material with a low reluctance would have a high permeability.

Magnetic poles. The magnetic force surrounding a magnet is not uniform. There exists a great concentration of force at the ends of a magnet and a very weak force at the center. Proof of this can be obtained by covering a glass with iron filings and placing the glass on top of the bar magnet. (See figure 1-6). As can be seen, many filings will cling to the ends of the magnet while very few adhere to the center. The two ends, which are the regions of concentrated lines of force, are the north and south poles of the magnet. Both poles have equal magnetic strength.

If a bar magnet is suspended freely on a string, it will align itself in a north and south direction. When this experiment is repeated, the same pole of of the magnet will always swing toward the North Pole of the Earth. Therefore, it is called the *north-seeking pole* or simply the north pole. The other pole of the magnet is the *south-seeking pole*, or the south pole.

Magnetic fields. The space surrounding a magnet where magnetic forces act is known as the *magnetic field*. A pattern of this directional force can be noted in figure 1-6. If the glass is tapped gently, the iron particles will align themselves with the magnetic field surrounding the magnet.

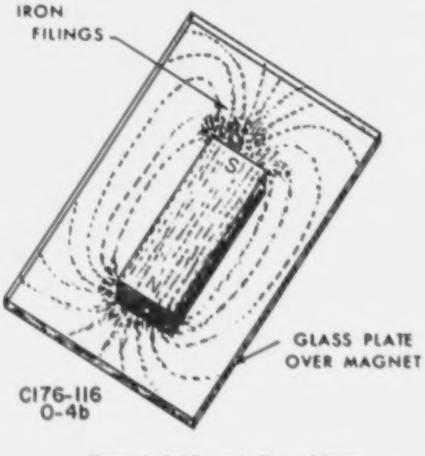

Figure 1-6. Magnetic lines of force.

The filings form a definite pattern, a visible representation of the forces comprising the magnetic field. The arrangement of the iron filings in figure 1-6 indicates that the magnetic field is very strong at the poles and weakens as the distance from the pole increases. You can see that the magnetic field extends from one pole to the other, constituting a loop about the magnet.

Magnetic shielding. There are no known insulators against magnetic flux. Any material, when placed within a magnetic field, will be penetrated by the passage of magnetic flux. Thus, protection from magnetic forces is obtained by redirecting the field. If a magnetic material such as soft iron is placed within a magnetic field, most of the lines of force, that take the easiest path, will pass through the magnetic material while completing a closed loop.

Redirecting the magnetic field is necessary to protect the sensitive mechanism of electronic equipment. Such equipment becomes inaccurate when subjected to the influence of stray magnetic fields. Therefore, if we surround the equipment with a material having a high permeability, the magnetic lines will flow through the surrounding material.

Care of magnetic materials. A piece of steel that has been magnetized can lose much of its magnetism by improper handling. If it is jarred or heated, it will lose some of its magnetism. If this steel formed the horseshoe magnet of a meter, the meter would no longer give accurate readings. Therefore, care must be taken when handling instruments containing permanent magnets. Severe jarring or subjecting the instrument to high temperature will damage the device.

Electromagnetism. Let's explore the idea of electromagnetism by first examining an electromagnet. An electromagnet is an electrically excited magnet capable of exerting mechanical force. Present day examples of electromagnets include the starter solenoid on an automobile, electromechanical input-output devices used with computers, and the simple doorbell. There are many more. Each of these particular devices operate on the principle of a current-carrying conductor wrapped around a soft iron core.

Magnetic field about a straight wire. We can prove the existence of a magnetic field surrounding a conductor-carrying DC. Figure 1-7 illustrates the experimental procedure used. Note that a straight piece of wire is passed through a hole in a piece of glass and connected to a source of DC through a rheostat and switch. By sprinkling iron filings over the glass and then tapping it gently, the filings will arrange themselves in circles about the wire. If two magnetic compasses are placed on the glass, the compass needles will point in the direction of the magnetic lines of force, as shown in figure 1-7. The north pole of each compass indicates the direction of magnetic lines of force. In this experiment the magnetic lines of force will travel in a counterclockwise direction. The result of this experiment shows that a magnetic field does exist about a current-carrying conductor and that the field also has direction. If the battery is reversed, the direction of the current in the circuit is reversed. The direction of both compass needles will then change by 180°. Thus, a change in the direction of current produces a change in the direction of the magnetic field. The important point to remember with respect to the above experiment is that whenever an electric current is flowing, a magnetic field exists.

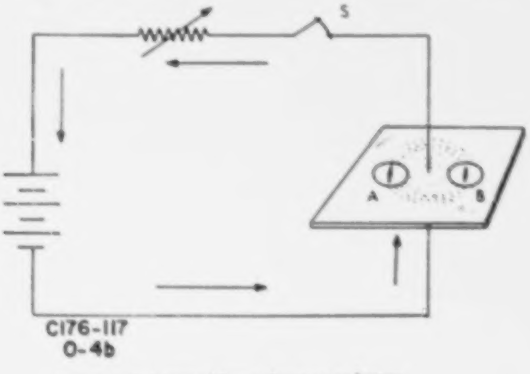

Figure 1-7. Lines of force about a conductor.

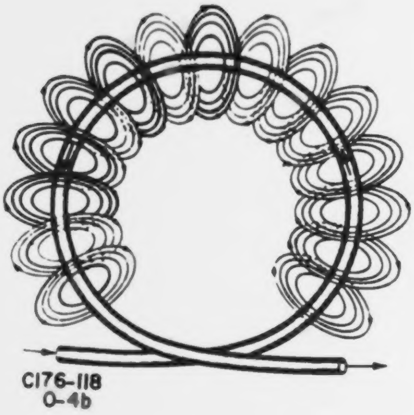

Figure 1-8. Magnetic field about a loop.

Magnetic field about a coil of wire. Let's take a straight wire and form it into a loop as in figure 1-8. The magnetic lines around the wire are as shown. With current flowing in it, the loop of wire acts like a short bar magnet. The face of the loop that the lines enter is the south pole and the face that they leave is the north pole. If you wind several loops to form a coil or solenoid, as shown in figure 1-9, a more powerful magnetic field will be created. Inside the coil, the lines are concentrated to form a power field, while outside the coil, they are spread out.

A coil with current flowing in it, as in figure 1-9, is the equivalent to a bar magnet. Its magnetic field has the same shape as the field of a bar magnet, and it obeys the same laws of magnetism that a bar magnet obeys. That is, the unlike poles of two coils attract each other and the like poles repel. If the coil is free to rotate in a horizontal plane and is placed in a magnetic field, it will rotate, as will a compass needle, to take such a position that the lines inside the coil are parallel to the lines of the field.

Electromagnets. Very strong magnets can be made by winding the coil around a piece of iron or steel (such constructed magnets are called electromagnets). The reluctance of iron or steel is so much lower than air that the same electric current in the coil sets up thousands of times more lines of magnetism than with an air core. Of course,

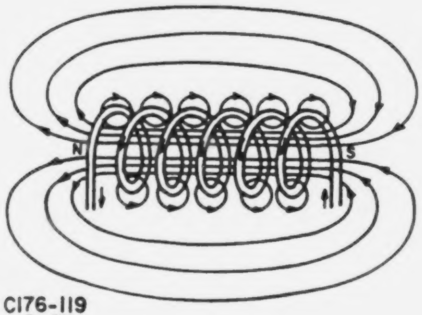

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Figure 1–9. Magnetic field about a coil.

the larger the electric current, the more lines will be set up in the core and thus the more powerful will be the magnetic field. Also, the more turns of wire wrapped around the core, the stronger the field. A field of given strength can be produced by using many turns of wire carrying a small current or by using a few turns of wire carrying a larger current. Thus, an electric current of 2 amperes flowing in a coil of 5,000 turns will produce the same number of lines as a current of 20 amperes flowing in a coil of 500 turns. The product of the number of turns in a coil and the amperes flowing in the coil is called the *ampere-turns* of the coil. Two coils with same number of ampere-turns will, if their cores are identical, produce magnetic fields of the same strength. The same product of amperes and turns gives the same effect, no matter what the separate values of current and turns may be.

If, in a coil containing an iron core, the current is continually increased, a point is reached eventually where further increases in current add so few lines to the flux already in the core that it becomes uneconomical and impractical to attempt to add more lines. When this point is reached, the core is said to be saturated. Sometimes, the current in the coil is deliberately made so large that saturation of the core takes place. It is usually undesirable, however, for this to happen.

Now let's place a bar of iron or soft steel in the magnetic field of a coil. The bar will become magnetized. Since the bar has less reluctance than air, magnetic lines flow through it. If the field is strong enough, the tendency of magnetic lines to shorten themselves causes the bar to be pulled into the coil until its center is near the center of the coil where the field is most intense. If you place the bar on the other side of the coil, it also will be drawn into the coil. The bar becomes magnetized by the field of the coil in such a way as to be attracted into the coil.

Exercises (203):

1. What is magnetism?

2. Name two types of magnets.

3. Name two types of artifical magnets.

4. What is reluctance?

5. What is residual magnetism?

6. What is retentivity?

7. What is permeability?

8. What are the regions of a magnet called in which the lines of force are concentrated?

9. How may sensitive instruments be protected from stray magnetic fields?

10. Name two things that will damage a magnet and cause them to lose their magnetism.

11. What is an electromagnet?

12. If a piece of wire with electron flow in it is made into a coil, what type of magnet is it equal to?

13. Taking the coil of wire in the previous question and putting a piece of iron or steel through the coil will produce which type of magnet?

14. What does the term "saturated" mean when used with electromagnets?

15. Explain the action of an electromagnet.

204. Cite principles of DC motor operation.

Principles of Motor Operation. To understand the principles of operation of a DC motor, you must have a knowledge of magnetism. In previous paragraphs we learned that a magnetic field exists around any current-carrying conductor. The strength of the magnetic field depends on the amount of current flowing in the conductor. When a current-carrying conductor is placed in a fixed magnetic field, the interaction of the two magnetic fields causes the conductor to move. The direction of movement depends on the direction of current flow into the conductor and the resulting direction of the magnetic field about the conductor. Figure 1-10 illustrates this point. There is also a rule which can be used to determine the direction of movement. This rule is called the "right-hand motor rule" and states: "Point the index finger of the right hand in the direction of the external magnetic field (N to S). The second finger points in the direction of current flow. The thumb indicates the direction of motion." Don't confuse this rule with the left-hand rule, used to determine the polarity of a coil.

Basic Direct-Current (DC) Motors. If we suspend a coil in a permanent magnetic field in such a manner as to allow the coil to rotate, the torque (turning force) created by the magnetic field causes the coil to rotate. This coil assembly is referred to as an *armature*. Now, connect a shaft with an attached commutator and brush assembly to the armature. These components, as shown in figure 1-11, are used to construct a basic DC motor. When a motor is constructed in this manner, the coil (armature) rotates because of the laws of magnetism.

Figure 1-11 shows a simplified DC motor with its coil (armature) in different positions. Note that the current-carrying coil is connected to a battery through the use of brushes and commutator segments.

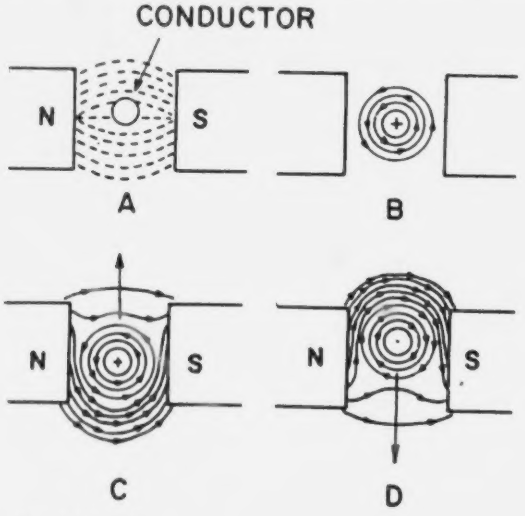

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Figure 1-10. Conductor in a magnetic field.

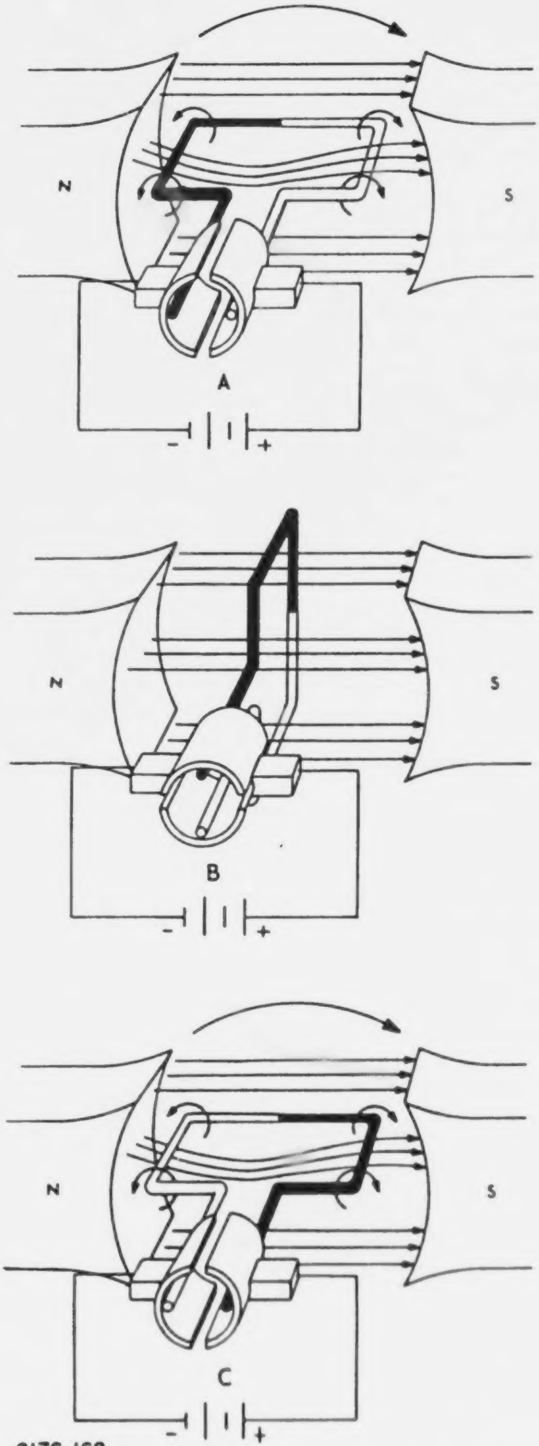

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Figure 1-11. DC motor operation.

In figure 1-11,A, current through the dark portion of the coil sets up a counterclockwise field; current through the white portion sets up a clockwise field. The interactions of these fields with the field of the pole shoes develop a torque that causes the coil to move in a clockwise direction.

When the coil reaches the neutral plane, as shown in figure 1-11,B, coil current drops to zero. At this time, however, the coil has built up enough momentum to swing past the neutral plane to the position shown in figure 1-11,C. The action of the commutator and brushes causes a reversal of the direction of current flow in the coil. As a result of this, torque remains in a clockwise direction.

Counter-Electromotive Force. As the coil (armature) of a motor starts to rotate, the armature windings move through the permanent magnet's magnetic field. When the armature cuts through the magnetic field, a voltage will be inducted into the armature. The induced voltage is opposite, or opposes the applied voltage, and is called *counter-electromotive force* (CEMF). The effective electromotive force, then, is the applied voltage minus the induced voltage (counter-electromotive force). This CEMF acts as a current regulator for the motor.

When current is first applied to a motor, there is no CEMF, because the armature is not turning. At this moment, armature current is at its maximum. As armature speed increases, inducing a CEMF, armature current decreases. When placing a load on the motor, its speed drops, thereby reducing the CEMF. As the CEMF drops, the applied voltage increases enough to overcome the added load. The motor adjusts itself to speed by drawing only enough current to produce the torque needed to do a specific job.

Thus, CEMF limits armature current to a safe value, and since CEMF strength varies with motor field strength and motor speed, it also effectively regulates armature current as these two factors change.

Exercises (204):

1. What rule is used to determine the direction of movement of a conductor in a magnetic field.
2. What unit is used to reverse the direction of current flow to the coil (armature) of a DC motor?
3. What principles govern the movement of the coil (armature) in a DC motor?
4. Name two ways of varying the strength of CEMF.
5. Explain effective electromotive force.
6. What prevents the current of a DC motor from becoming so high that it destroys the coil (armature)?

1-2. AC Theory and Circuits

Alternating current (AC) derives its name from the fact that electron flow in an AC circuit is continually reversing directions. Current flows first in one direction, then the other. AC current is the most commonly used electrical power in the world. Until a few years ago, the use of alternating current in aircraft was limited to a few instrument circuits and other special installations. Today, however, AC is usually used as the primary electrical power source. The change from direct current (DC) to alternating current (AC) was primarily due to the advantage of less power waste during transmission, and the elimination of insulation and brush problems normally encountered with DC current. In the following paragraphs, we will discuss the principles of alternating current, inductance, capacitance, time constants, transformers, and AC motors.

205. Define alternating current and cite characteristics of AC sine waves.

AC Sine Wave. Alternating current is the term used to describe current that periodically reverses its direction. The AC sine wave, as shown in figure 1-12, has become the means or symbol used to represent AC. In fact, when we think of AC, we automatically think of the AC sine wave. Notice the horizontal line in the figure that divides the sine wave into two equal parts. One part is above the line and the other is below. The portion above the line represents the *positive* alternation, and the portion below the line represents the *negative* alternation. The sine wave starts at zero and increases in value to a maximum positive peak, then returns to zero. It then goes down to a maximum negative peak, and again, returns to zero. The travel of current, as represented by the sine wave (from zero to a

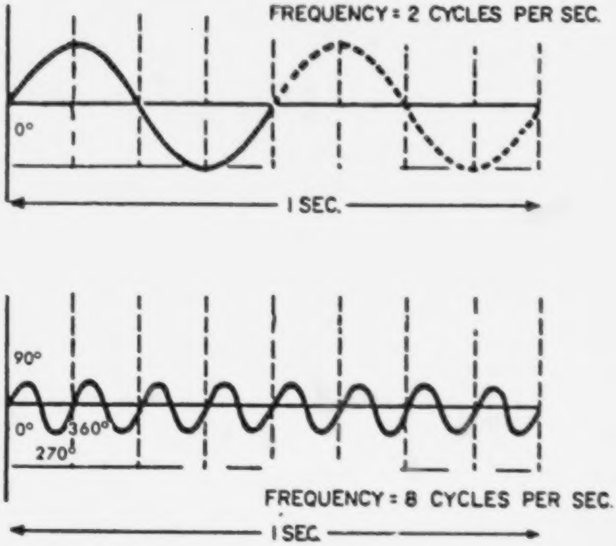

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Figure 1-12. Frequency in Hertz.

positive peak, down to a negative peak, and back to zero), is called one complete cycle. Hence, there are two alterations, one positive and one negative, in a full cycle. The positive and negative alternations are often called *half-cycles*.

The number of cycles that occur in a given time (second) is called *frequency*. (Refer to fig. 1-12). The unit of measurement for frequency is tHe hertz (Hz). Instead of saying, "60 cycles per second," you say, "60 Hertz."

Phase. A phase relationship is used to express a condition in which two moving objects are changing, in or out, of step. The phase angle, or phase difference, is used to denote a time difference between two quantities alternating at the same frequency. This difference is generally expressed in terms of electrical degrees. A phase relationship must exist between any two different AC voltages, between any two different currents, or between voltage and current when in the same circuit.

In the preceding paragraphs we pointed out that a positive peak is reached at the 90° position. At the same instant of time, however, another voltage source might be producing the same voltage value with a negative peak. If these two voltages are shown one above the other on a chart, we have the condition represented by curves I and II of figure 1-13. In the figure, voltage curve II has reached the 180° position of its cycle, at the same instant the voltage in curve I is at its 0° position. Thus, the two plotted voltages are out of phase by 18°. It may be said that phase angle, or phase difference, is the number of electrical degrees (E°) between the peaks of two different sine waves.

If like peaks occur at the same time, even though one has a greater magnitude than the other, they are said to be *in phase*. A voltage or current is said to lead another voltage or current if its peak occurs a few degrees before the similar peak of the other. The second voltage or current is said to *lag*, since its peak occurs a few degrees after the first.

If the voltage curve is compared to the current curve in the same circuit, it might be assumed that the two curves are always in-phase. This is true in circuits that contain resistance only. However, if the circuit contains coils or capacitors or both, voltage and current will be out-of-phase, but never by more than 90°. If a 90° phase difference exists, the current will be zero when the voltage is at peak.

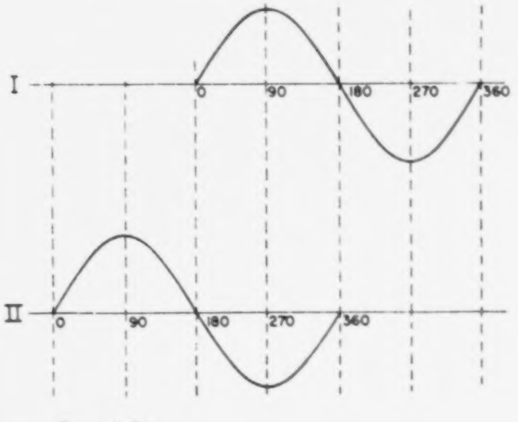

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Figure 1-13. Phase relationship.

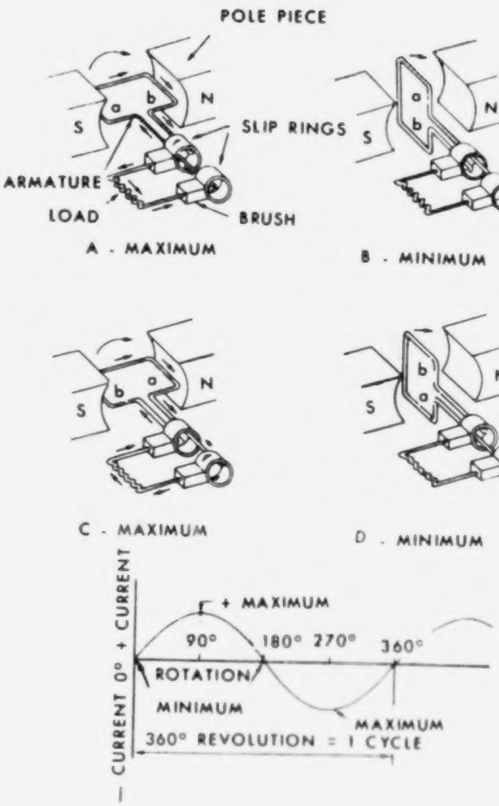

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Figure 1-14. Simple AC generator.

Generation of AC. Alternating current is produced by AC generators, which operate on the principle of induction. Three requirements are necessary for induction—a conductor (coil of wire), a magnetic field (permanent magnet), and relative motion between the two to cut across magnetic lines of force.

An AC generator has a conductive coil (armature) which rotates in a magnetic field. Figure 1-14 shows a very basic AC generator, with a one wire conductor. Note that the conductor is in the form of a loop and located in a magnetic field between the poles of a permanent magnet. When one side of the loop is traveling up, the other side is moving down. As the conductor (armature) first moves through the magnetic field, a voltage is induced into the conductor. Then, as the loop rotates to a vertical position where no lines of force are cut, current decreases to zero. As the loop continues to rotate, force lines are again cut, however, in the opposite direction. The loop has now completed one full cycle. During one-half of the revolution, the current in a closed loop rotating in a magnetic field flows in one direction; during the other half revolution, current flows in the reverse direction.

In order to make use of the voltage induced into the loop, sliprings are attached to the two ends of the loop. The sliprings transmit the current to the brushes which, in turn, allow current flow to an external circuit.

Exercises (205):

1. Define alternating current.

2. Name the components of a basic AC generator.

3. What term is used to describe the unit of measurement for frequency?

4. When a sine wave starts at zero and increases to its maximum positive or negative voltage, what is this voltage called?

206. Explain inductance, capacitance, and time constants.

Inductance. Inductance is a property of a circuit that opposes any change in current flow. The inductance does not oppose current flow itself, only *changes* in current flow. Where current is constantly changing, as in an AC circuit, opposition caused by inductance is always present. The symbol that represents inductance is "L," and the unit of measurement for inductance is the "henry (H)."

If a conductor is wound in the form of a coil, the magnetic field about each turn of wire is linked with each of the other turns. As the current through the coil varies, the strength of the field around the coil increases or decreases accordingly. By strengthening a magnetic field, magnetic lines expand outward and move across the other turns of the coil. This motion of the magnetic field, cutting across the other loops, induces a voltage in the loops that is in opposition to applied voltage. This self-induced voltage is called counter-EMF (counter-electromotive force), because of its opposition to any change in the amount of current flowing at that instant. Therefore, if current increases, the counter-EMF tries to prevent the increase; or if current decreases, the counter-EMF opposes the current decrease. Therefore, the voltage across the coil leads current by 90°; that is, the voltage reaches its maximum value, 90°, ahead of current.

Factors Affecting Inductance. The four physical factors that affect the inductance of a single-layer coil are: the number of turns in a coil, the diameter of the coil, the coil length, and the type of material used for the core.

Number of turns in a coil. First, notice how the number of turns affects the inductance of a coil. Increasing the number of turns in the coil has the same effect as increasing the number of conductors in the field of a basic generator. In the basic generator, it increases the output; in a coil, it increases the CEMF. Doubling the number of turns increases the inductance of the coil by a factor of approximately four.

Coil diameter. The second factor is the coil diameter. Assume that you have two coils with the same number of turns and with the same diameter of conductors. The cores of each coil are the same length. However, one core is much larger than the other core. The larger core provides an easier path for the magnetic flux than the core with the smaller cross-sectional area. Again, this has the effect of increasing the strength of the magnetic field and, in turn, increasing the inductance of the coil. The inductance of a coil increases directly as the cross-sectional area of the core increases. Doubling the radius of a coil, therefore, increases the inductance by a factor of four.

Length of the coil. The third factor that affects the inductance of a coil is the length of the coil. This time, assume that we have two coils with the same number of turns and the same diameter of conductor. The core also has the same cross-sectional area. However, one core is much longer than the other core, and the turns of the conductor are spaced further apart. The coil with the longer core has few flux linkages, due to the space between each turn, and therefore, low inductance. The other coil has the same number of turns, but they are closely spaced, making a relatively short coil. This close spacing increases the flux linkage, increasing the inductance of the coil. A coil with twice the length of another will have half the inductance, or doubling the length of the coil halves its inductance.

Type core material. The fourth physical factor is the type of core material used with the coil. For example, a soft iron magnetic core provides a better path for magnetic lines of force than a nonmagnetic core (such as air). The soft iron magnetic core's high permeability has less reluctance in the magnetic flux, resulting in more magnetic lines of force. This increase in the magnetic field increases the

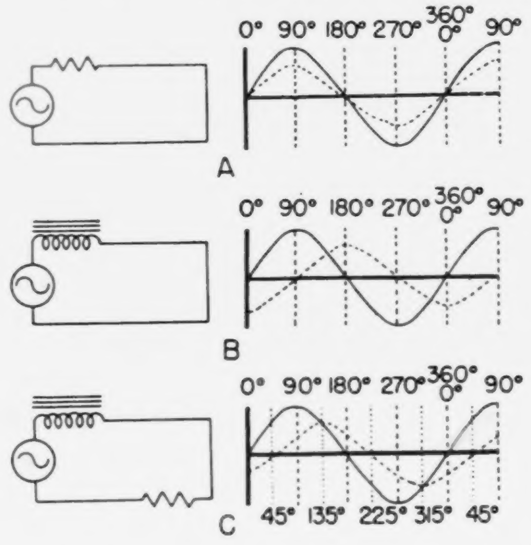

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Figure 1-15. Inductive and resistive phase relationship.

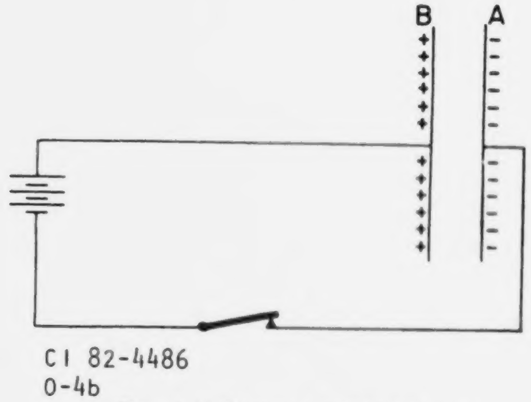

Figure 1-16. Capacitor in a simple DC circuit.

number of lines of force cutting each loop of the coil, thus increasing the inductance of the coil.

An additional factor is the type of coil winding used. Assume that we have a coil with close spacing and wound in layers. This has the effect of obtaining maximum flux linkage. Thus, the layer-wound coil has larger inductance values than the same size single-layer wound coils.

Inductive Reactance. The current in a purely inductive circuit lags the voltage by 90°. The reason for this lag is the opposition to alternating current offered by inductance. Phase relationship of inductive and resistive circuits is shown in figure 1-15. Circuits that contain resistors dissipate electrical energy in the form of heat. However, in an inductive circuit, its energy is fed back into the circuit as opposition to current flow. The magnetic field expands and collapses; thus, it reacts, but dissipates no power. For this reason, we call the opposition "reactance," and use the symbol X. Reactance of a coil is "inductive reactance" (XL) and is defined as the opposition to current flow offered by the inductance of a circuit.

Impedance. Impedance is the total opposition to current flow in an AC circuit. This opposition includes both resistance and reactance (inductive reactance (XL), capacitive reactance (XC), or any combination thereof). Since each of these factors opposes current in a different manner, it is confusing to refer to each, individually or combined, as "resistance." To recognize each as being a distinct current-limiting factor, and to provide a standard term to express their combined effect, the word "impedance" is used. It is also used in place of any one of the opposing factors. For example, in an inductive circuit (one having inductors only) where the inductive reactance is determined to be 200 ohms, the circuit is said to have an impedance of 200 ohms. Impedance is the summation of the various factors within an AC circuit which offer opposition to current flow. The symbol for impedance is Z, and the unit of measurement of impedance is the "ohm."

Capacitance. If you have ever lived in a small town, you have no doubt noticed the town's water supply tank. The water is stored ready to use and kept high above ground, which gives it the potential energy to be carried to the customer. In an electrical circuit, the capacitor, often called a condenser, serves the same purpose by storing electrical charges. Since this unit has the ability to store an electrical charge, it also has a certain capacity. This electrical capacity is called capacitance. The letter C is the symbol for capacitance. The unit of capacitance is the farad. The farad is usually too large a unit for most applications, and smaller units are commonly used. The smaller unit most frequently used is the microfarad (μf—many sources use MFD). Essentially, a capacitor consists of two conducting surfaces (plates separated by an insulating material, such as glass, air, or mica) which is known as the dielectric.

As previously mentioned, the principle feature of a capacitor is its ability to store a quantity of electricity. Let's refer to figure 1-16 to illustrate this point. With the switch open, the plates of the capacitor are neutral, since there are an equal number of free electrons in each of the plates. When the switch is closed, however, the battery acts as a pump; the positive side of the battery immediately attracts electrons from plate B of the capacitor. The deficiency of electrons causes plate B to become positively charged (excess of protons). The negative side of the battery places an excess of electrons on plate A. Electron flow cannot cross the dielectric material. However, electrons are moving away from plate B to the battery, and an equal number of electrons move into plate A from the battery. This electron movement is at maximum the instant the switch is closed, and continually decreases until it reaches zero. As the decrease reaches zero, the potentials at plates A and B of the capacitor are the same as those of the battery. Now, if the switch is opened, the plates of the capacitor retain their charge.

The amount of charge that a capacitor can hold depends on three factors:

(1) Plate area - the larger the plate the more electrons it can hold; thus, it has more capacitance.

(2) Distance between the plates - when the distance is increased, the capacitance is decreased because the greater distance reduces the attraction between the two forces.

(3) Type of dielectric - the material used in the construction of capacitors determines the amount of voltage that may be applied, and the quantity of energy that can be stored.

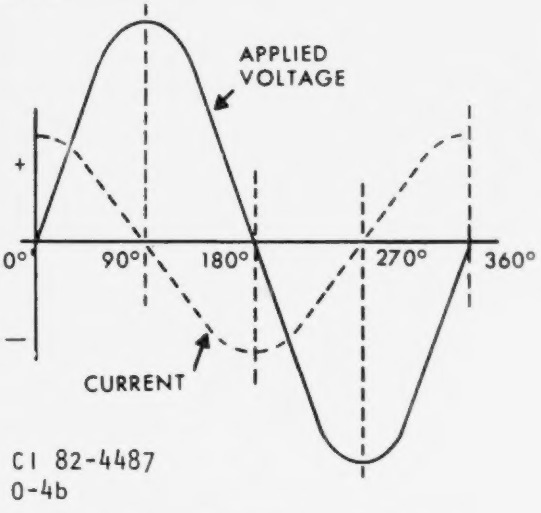

Figure 1-17. Phase relationship in a capacitive circuit.

Current and Voltage Relationship. If a capacitor is placed in an AC circuit, the capacitor is charged during one-half cycle, and discharged on the other half-cycle. The instant that an AC power source is applied, there is no opposition, and maximum current flows. As voltage reaches its maximum value and stops increasing, there is no current flow in the circuit. In other words, the applied voltage is at *maximum*, and the current in the circuit is at *zero*. Therefore, we can say that a phase difference of 90° exists between the voltage and current. This difference is illustrated in figure 1-17. When the applied voltage starts decreasing from its maximum positive value, the voltage across the capacitor decreases, and the capacitor starts to discharge in a direction opposite to that of applied voltage.

The reversal in current direction in the circuit occurs 90° before the reversal in polarity across the capacitor; therefore, the current leads voltage by 90° in a purely capacitive circuit.

Types of Capacitors. In the construction of a capacitor, the size of the plates, spacing between the plates, and the dielectric materials not only determine the capacitance, they also determine the size and shape of the final product. Capacitors are divided into two principal classes: fixed and variable.

The fixed capacitors are used where a special value of capacitance is needed. These capacitors usually are named by the dielectric used. They include paper, oil, mica, electrolytic, and ceramic.

Variable capacitors are used in circuits where the capacitance requires adjustment. The variable types are named according to their function and include tuning, trimmer, padder, and neutralizing capacitors. To indicate the value of capacitance, a color code similar to the one for resistors is used.

Paper capacitors. Paper capacitors are in common use because of their low cost and small size. The dielectric material is usually waxed paper that is a porous material; therefore, the paper capacitors are seldom used above 600 volts. The plates are long, flat strips of tinfoil and the paper is placed between them as the dielectric. All three are rolled together into a cylinder. The completed cylinder usually is placed in a metal or cardboard container and sealed with wax, or pitch, to keep out the moisture. The outside foil is normally connected to the ground side of the circuit to create an electrostatic shield around the capacitor.

Oil capacitors. The oil capacitor is similar in construction to the paper type. The oil used for the dielectric has a much higher breakdown voltage and can handle medium-high voltages (above 600 volts). Such capacitors are designed for high power and usually are found in transmitter circuits.

Mica capacitors. Mica capacitors have capacitance values between 5 and 50,000 picofarads (pf) and are used in circuits subjected to voltages up to 7,500 volts. These low-capacitance components are used in high-frequency circuits. The high breakdown voltage of mica allows the high-frequency, high-voltage capacitors to be small in size compared to the same capacity and breakdown voltage of a paper capacitor.

Electrolytic capacitors. The electrolytic capacitor is encased in an aluminum can. The can is the negative terminal filled with an electrolyte (a liquid, nonmetallic conductor) that forms the negative plate. There is an aluminum post that acts as the positive plate. This post is covered with an oxide of film that acts as the dielectric. In this case, the capacitor type is not named by the type of dielectric used. The electrolytic capacitor has a definite polarity and is used only in DC circuits. The reason for this is that if the current were reversed, the oxide coating on the positive plate would break down and current would flow through the capacitor until oxide formed on the negative plate.

Electrolytic capacitors are constructed for AC operation by connecting two units back to back. The plates of such a capacitor have previously formed oxide films. The AC electrolytic capacitor is designed to present an insulation dielectric to both polarities; this design is used for starting AC motors where the capacitor creates a phase shift for starting.

To overcome the disadvantage of the wet electrolytic capacitor, a dry electrolytic was developed. The construction of this type uses two flexible aluminum sheets separated by a jelly-like electrolyte fixed to the separating gauze or paper. The method of construction is similar to that used for paper capacitors. The electrolytic capacitors are made in single and multiunit sections; this puts more than one capacitance value in one container.

Electrolytic capacitors generally are found in low-voltage power supplies. The case usually shows the polarity for connecting it in a circuit. In operating conditions, they handle low frequencies, relatively high power, and voltages up to 600 volts. Another disadvantage of the electrolytic capacitor is the high-power loss. A good electrolytic capacitor will constantly show a DC resistance of little more than 1 megohm, compared to the minimum of 200 megohms of a good paper capacitor of equal value.

Ceramic capacitors. With the development of higher frequencies used in communications and television, there came a need for small capacitors with a high dielectric strength. The ceramic capacitor was designed to fill these needs. Ceramic capacitors range from .5 pf to .01 pf and can be used in low-power, high-voltage circuits (up to 30,000 volts). They are extensively used in television high-voltage power supplies. The construction is quite simple: A hollow ceramic cylinder is coated inside and out with silver paint. Contacts to the coatings are placed at each end of the cylinder. The silver conductors are separated from each other by the ceramic cylinder. The finished capacitor is quite small physically and, because of its size, shape, and coloring, it is sometimes mistaken for a resistor.

Variable capacitors. Variable capacitors are used for low, medium, and high frequencies. The low-frequency values range from 250 to 500 picofarads (pf). For higher frequencies, capacitors between 25 to 150 pf are used. For very high frequencies, values under 10 pf are used and referred to as microcapacitors.

In the variable capacitors that use air for a dielectric, the power and voltage in the circuit determine the capacitor's physical size. Air has a low breakdown voltage; therefore, the plates need to be spaced far apart if a large voltage is applied. The plates are connected in such a manner as to be able to pass next to each other without touching. One set of plates is on a rigid frame (stator); the other set is on a movable shaft (rotor). As the plates are rotated, the plate area producing the amount of capacitance can be increased or decreased. You probably have seen this type of capacitor in the tuning circuit of your radio.

The adjustable capacitor is another type of variable capacitor, designed to be set to a desired amount of capacitance and left that way. Adjustable capacitors are made with mica or ceramic dielectrics. The adjustable mica capacitor consists of a spring-metal plate separated from another plate by a thin mica strip. The spring-metal plate has a screw-type adjustment used to set the distance between the plates. Adjustable capacitors are in two groups: trimmers and padders. Trimmers are used in parallel with large variable capacitors, and padders are used in series with them. The trimmer is sometimes indicated by a small T on the schematic diagram. The ceramic adjustable capacitors are similar to the mica in size and are also adjusted with a screwdriver. The plates of the ceramic capacitor are set in the ceramic material and are rated up to 500 VDC.

Time Constants. The time constant, T, of an RC circuit may be defined as the time interval required for a capacitor to charge up to 63 percent of the applied voltage, and is numerically equal to:

$$T = RC$$

where T is the time constant in seconds, R is the resistance in ohms, and C is the capacitance in farads. Therefore, as the capacitance or resistance (or both) in the circuit is increased or decreased, the time constant, T, must also increase or decrease.

The time constant, T, of an RL circuit is the time required for the circuit current to build up to 63 percent of its maximum value. It is numerically equal to:

$$T = \frac{L}{R}$$

where T is the time constant in seconds, L is the inductance in henries, and R is the resistance in ohms. The time constant of and RL circuit may be inceased (or decreased) by increasing (or decreasing) the value of L or R (or both).

The time constant, T, of a circuit provides a measure of how rapidly the voltages and currents in a circuit can react to instantaneous changes in the input signal. A small time constant results in rapid circuit response to the input signal, while a large time constant requires a comparatively long time to complete the reaction.

Exercises (206):

1. Explain inductance, and give its symbol.

2. What unit of measure is used for inductance, and what symbol represents this unit of measurement?

3. In a purely inductive AC circuit, ____________ will lead ____________ 90°.

4. What factors determine the amount of inductance a coil possesses?

5. What is impedance, and what term is used to express its value?

6. What factors determine the amount of charge, or effectiveness, of a capacitor?

7. Name the term used as the unit of measurement for capacitance, and identify the symbol that represents this unit of measurement.

8. In a circuit that is purely capacitive, if voltage is at a maximum value, what is the current value?

9. What is the phase relationship of voltage and current in a capacitive circuit?

10. Which letter is used as the symbol for capacitance?

11. Name the two classes of capacitors.

12. Paper capacitors are seldom used where the voltage will exceed ____________ volts.

13. What circuits are oil capacitors designed for?

14. In what circuits are mica capacitors normally used?

15. Which type of capacitor is designed primarily for DC circuits?

16. State the disadvantage of the electrolytic capacitor.

17. What type of capacitor is used in low-power, high-voltage (up to 30,000 volts) circuits?

18. What is the time constant of an RC circuit?

19. What is the time constant of an RL circuit?

207. State how transformers work.

Transformers. A transformer does just what its title says, transfers electrical energy from one circuit to another. It does this by mutual induction, a term we discussed earlier. We are now going to discuss transformer construction, the step-up and step-down turns ratios and transformer operation with loaded secondary windings.

Transformer construction. A transformer is a device that uses inductance to transfer electrical energy from one circuit or winding to another. A simple transformer consists of two coils of wire placed on some type of core. These coils are called windings. The winding that is connected to the source is the *primary winding*. The winding that supplies energy to the load is called the *secondary winding*. A transformer may have several secondary windings. Frequently, additional connections are made to a transformer winding between the end connections. These additional connections are called *taps*. A tap placed at the center of a winding is called a *center tap*.

Transformers use various materials for their cores. The air-core transformer is commonly used in circuits carrying radio-frequency energy. Radio-frequency transformers also use powdered iron, brass, and aluminum cores. Transformers used in low-frequency circuits require a core of low-reluctance magnetic material to concentrate the field about the windings. This type of transformer is called an iron-core transformer. Audio and power transformers are of the iron-core type. Often iron cores are fabricated from a number of thin silicon steel strips (laminations) covered with an insulating varnish before they are assembled.

Step-up and step-down turns ratios. The ratio of the number of turns in the primary to the turns in the secondary is called the *turns ratio*.

If an input of 10 volts at 60 Hertz is applied to the primary winding and the no load is connected to the secondary winding, the primary acts as a simple inductor. The current flowing in the primary will depend on the applied voltage (amplitude and frequency) and the inductive reactance of the primary. This current produces a magnetic field that cuts the primary and secondary as it expands and collapses. This produces a CEMF in the primary (self-inductance) that nearly equals the applied voltage, and it induces a voltage in the secondary (mutual inductance). The amplitude of the voltage induced into each turn of the secondary will be identical to the CEMF produced in each turn of the primary.

When 10 volts is applied across 10 turns of the primary, a CEMF of nearly 1 volt per turn develops. A 2-turn secondary will then have an induced voltage of 2 volts (1 volt per turn). Thus, a turns ratio of 10 (primary) to 2 (secondary) or 5 to 1 has produced a step-down in voltage, from 10 volts (primary) to 2 volts (secondary) or 5 to 1. The transformer is described as having a step-down turns ratio.

With a transformer having a step-up turns ratio of 1:4, an input of 10 volts applied to the primary produces 40 volts in the secondary. The turns ratio equals the voltage ratio in all cases.

The extent to which magnetic lines of the primary cut across the secondary is expressed as a "coefficient of coupling." If we said a transformer had a coefficient of coupling of 1, this means that all of the magnetic lines of the primary link the secondary. That is, 100 percent of the flux lines produced by the primary winding cut the secondary winding. A coefficient of coupling of .9 indicates that 90 percent of the flux lines produced by the primary cut the secondary. A cofficient of coupling less than 1 reduces the voltage induced in the secondary.

Transformer operation with loaded secondary. Up to now our discussion of transformer action has been with no load on the secondary; we considered induced voltage only. When a load is connected to the secondary winding of a transformer, current flows in the secondary. The magnetic field produced by current in the secondary interacts with the primary field. This interaction is truly mutual inductance, where both primary and secondary currents induce voltages. The magnetic field produced by secondary current is in direct opposition to the primary magnetic field and cancels some of the primary field. This reduces CEMF, and, as a result, primary current increases to nearly reestablish the primary field. To summarize, as current increases (with increased load) in the secondary, primary current increases.

Total power available from a transformer secondary must come from the source which supplied the primary. Remember, a transformer does not generate power, it merely transfers power from a primary circuit to a secondary circuit. If the transformer is 100 percent efficient, total primary power equals secondary power.

If a 100Ω load is connected to the secondary of a transformer with a step-up turns ratio of 1:10, 10 volts applied to the primary will produce 100 volts in the secondary. Current through the 100Ω load will be 1 amp. Power consumed in the load is (P = 1XE) 100 watts. With 10 volts applied to the primary winding of 10 , the primary current is 10 amps. Applying the power formula (P = 1XE) to the primary circuit yields 100 watts. Notice there is a step-up in voltage (1:10) and a step-down in current (10:1). Power supplied to the load comes from the source, and we have no losses in the coupling. This transformer is 100 percent efficient because output power equals input power.

Practical transformers, although highly efficient, are not perfect devices. They range from 80 to 98 percent efficient. Primary power must be slightly greater than secondary power to offset the decrease in efficiency. The losses associated with transformers are the same as the losses for inductors. Efficiency can be computed by dividing transformer output power by input power.

If there were a transformer that has a step-down turns ratio of 10:1, 100 volts applied to the primary will induce 10 volts in the secondary. If we use a 10-ohm load connected to the secondary, we will have 1 amp of current. Power consumed by the load is 10 watts (P = 1XE). Now the source must supply 10 watts of power. With 100 volts, the current needed to provide this power is The current is increased by the same ratio as the voltage decrease. Again, our calculations assume a 100-percent efficient transformer.

Exercises (207):

1. What are the windings called that are connected to the source voltage?

2. What are the windings called that are connected to the load side of the transformer?

3. What type of core material is required for transformers used in low-frequency circuits?

4. What is the transformer in exercise 3 called?

5. Define the term "turns ratio."

6. What type of ratio does a transformer have if, when we apply 10 volts to the primary, the voltage read across the secondary is 2 volts?

7. Define the term "coefficient of coupling."

8. Assume that a transformer has a coefficient of coupling of .9. What does this mean?

208. Cite principles of AC motor operation.

Induction Motors. Although there are several different types of AC motors, the induction motor is the type used most extensively. An induction motor, like most electrical machines, has two electrical circuits linked together by magnetic lines of force. When talking about DC motors, the circuits were called the *field* and *armature* windings. In the induction motor, the windings are called *sator* and *rotor* windings. The sator is that part of an induction motor which is stationary and can be compared to the field winding of a DC motor. The sator of an induction motor consists of several coil windings, which are wound on laminated stationary cores. The rotor is that part of an induction motor which rotates. In a DC motor, it is called an *armature*. There are two general types of rotors—the squirrel cage and the wound. Most induction motors use the squirrel-cage design.

One important point about induction motors is the fact that they do not normally use commutators and brushes. Instead, AC power is connected directly to the stator windings.

Principles of Operation. Induction motors operate on the principle of mutual induction. When an AC-power source is connected to the stator (primary winding), a magnetic field is established which cuts across and induces a voltage into the rotor (secondary). The induced voltage causes current to flow in the rotor which, in turn, creates another magnetic field around the rotor. The two magnetic fields repel, however, and the rotor remains stationary. A rotating magnetic field is necessary to cause the rotor to rotate. This is done by adding additional sets of windings to the stator. The windings are excited, one after the other, by currents that are 90 out of phase (for single- and two-phase motors).

Rotating Magnetic Field. To understand how a rotating magnetic field operates, an understanding of AC-phase relationship is necessary. Refer to figure 1-18, which shows a two-phase AC motor, as we explain how a rotating magnetic field is created.

Part A of the figure shows the sine wave for two-phase AC power. Phase 1 is indicated by the first sine wave, and phase 2, by the second sine wave. Phases 1 and 2 are two independent power supplies coming from the same source. These power supplies are 90° out of phase. This means that by moving 90° (B detail) from the zero reference point, phase 1 is at maximum value. At the same time, phase 2 is at zero. Therefore, we can say that current of phase 1 leads the current of phase 2 by 90°. Now, move 90° further to the 180° point (D detail). At the 180° mark, phase 2 is at

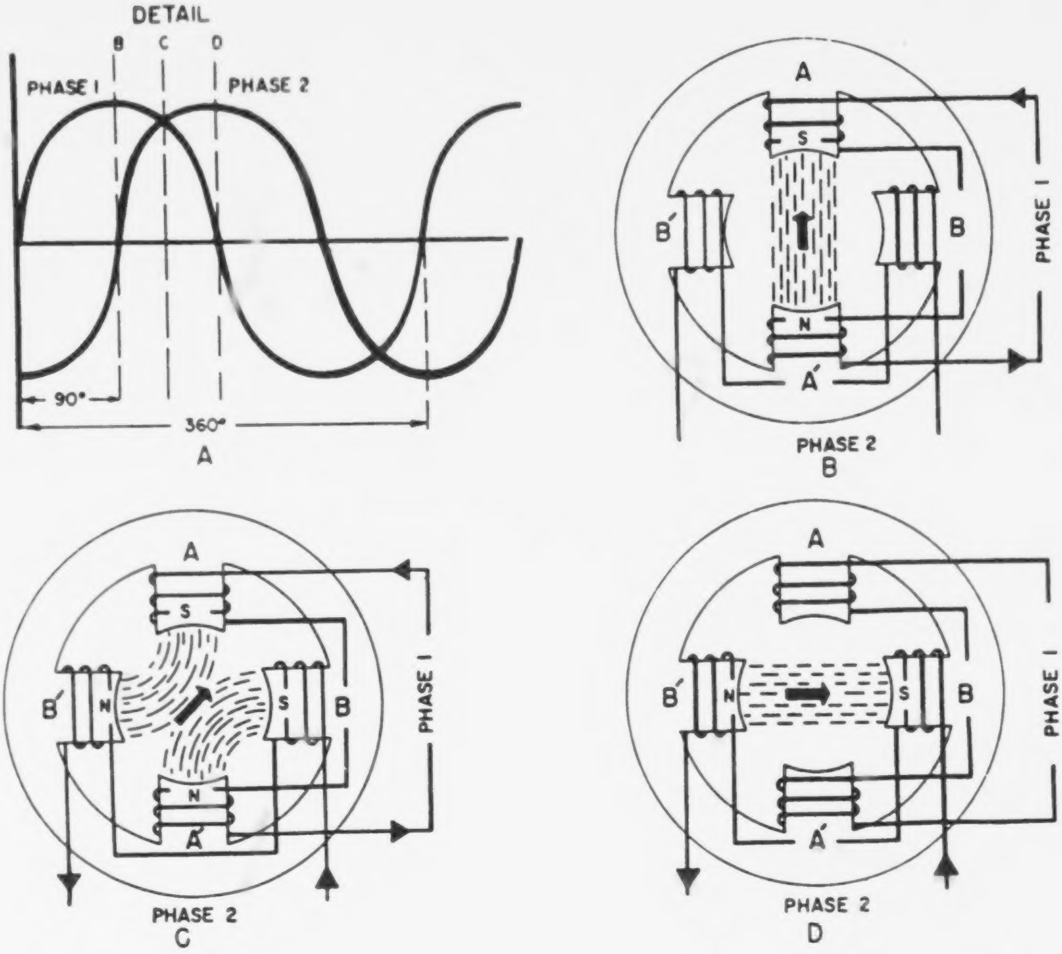

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Figure 1–18. Production of a rotating magnetic field.

maximum, and phase 1 has dropped to zero. (If another phase were added, all three phases will then be at a different value at the same point in time.)

A separate phase of power is connected to different sets of poles on the stator. The windings on each set of poles are wound in opposite directions to produce opposite polarity. The two sets of windings are excited, one after the other, by currents that are 90° out of phase. As each set is energized, a magnetic field is created. Then, as the other set is energized, the first field diminishes, and the second field appears in a rotated position. Thus, a rotating magnetic field is created which causes rotor torque in the same direction as the rotating field. This action is repeated during successive cycles of the flow of the alternating currents. Consequently, the rotor continues to revolve in the same direction within the field frame, as long as the two-phase currents are supplied to the two sets of coils. The magnetic field between the poles of a three-phase motor will rotate in the same manner.

The difference between the speed of the stator's rotating magnetic field and the rotor is called slip. The smaller the slip, the closer the rotor speed approaches the stator's rotating magnetic field speed.

Exercises (208):

1. What action causes the rotor of an induction motor to rotate?

2. What two types of rotors are commonly used in AC induction motors?

3. Explain slip.

4. DC motors use field and armature windings. What like components are used in the AC-induction motor?

1-3. Electronic Theory and Circuits

We have covered fundamentals of DC and AC. Now we will look at some of the electronic fundamentals you need to know. This section covers transistors, amplifier circuits, power supplies, and electronic voltage regulators.

209. Explain how bias effects a transistor.

Parts of a Transistor. Semiconductor devices that have three or more electrodes are called *transistors*. The term transistor was derived from the words *transfer* and *resistor*. There are many different types of transistors with individual characteristics, but the theory of operation is basic to all of them.

We will first review the construction and operation of the two-junction device. Then we connect the transistor in circuits to show the various configurations with their own characteristic curves. Finally, we will discuss the current transfer ratio or control characteristics for each configuration.

The three elements of the two-junction transistor are the (1) emitter, which gives off or emits current carriers (electron or holes); (2) base, which controls the flow of the current carriers; and (3) collector which collects the current carriers.

Classes of Transistors. Transistors are classed as PNP or NPN according to the arrangement of the N and P materials. Transistors have two junctions. One PN junction is between the emitter and the base; and the other PN junction is between the collector and the base.

One type of junction transistor is formed by introducing a thin region of P-type material between two regions of N-type material in a single crystal of germanium or silicon. The transistor so formed is called an NPN transistor. By introducing a thin region of N-type material between two regions of P-type material, a PNP transistor is formed.

Transistor bias. In normal operation, the emitter-base junction is forward biased and the collector-base junction is reverse biased. Forward bias at the emitter-base junction reduces the size and intensity of the emitter-base field. Therefore, the emitter-base junction is usually referred to as the low-resistance junction. Reverse bias at the collector-base junction increases the size of the collector-base field. Reverse bias opposes conduction by majority carriers; thus, the collector-base junction is referred to as the high-resistance junction.

Figure 1-19 is a pictorial diagram of two transistors showing the effect on the junction fields when the bias batteries are connected. The bias batteries are labeled V_{CC} for the collector voltage supply and V_{EE} for the emitter voltage supply. Notice that the forward bias (V_{EE}) reduces the junction field of the emitter-base junction, and that the reverse bias (V_{CC}) increases the junction field of the collector-base junction in both the NPN and PNP transistor.

The bias current paths through an NPN transistor are illustrated in figure 1-20, A. The solid arrows indicate current flow due to free electrons. The dotted arrows indicate current flow due to hole movement (valence band electron movement). Current flow in the external circuit is always due to the movement of free electrons. Emitter current (I_E) is shown leaving the emitter supply battery and flowing to the N-type emitter. Since electrons are the majority carrier in N material, the electrons will move through the emitter to the emitter-base junction field. Having gained energy from V_{EE}, the electrons will overcome the small opposition of the forward-biased junction and be injected into the base region. The base region is P-type material and the electrons are now minority carriers. As they move into the base region, some of them will recombine with available holes. The electrons that recombine will move out through the base lead as base current (I_B), and return to the emitter supply battery V_{EE}. Most of the electrons that move into the base region will come under the influence of the collector-base junction field. The direction of the reverse-biased collector-base field is such that minority carriers will be accelerated. The collector-base reverse bias is actually a forward bias condition for minority carriers in the base. Since the electrons are minority carriers at this time, they will be accelerated through the field and injected into the collector region. The collector is N-type material and the electrons are again majority current carriers. The electrons now move through the collector material to the positive collector

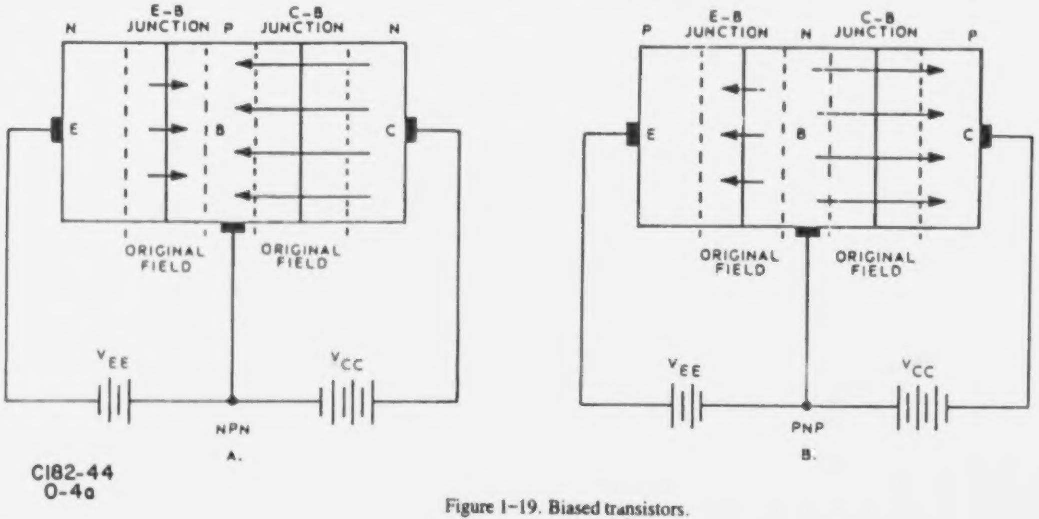

Figure 1-19. Biased transistors.

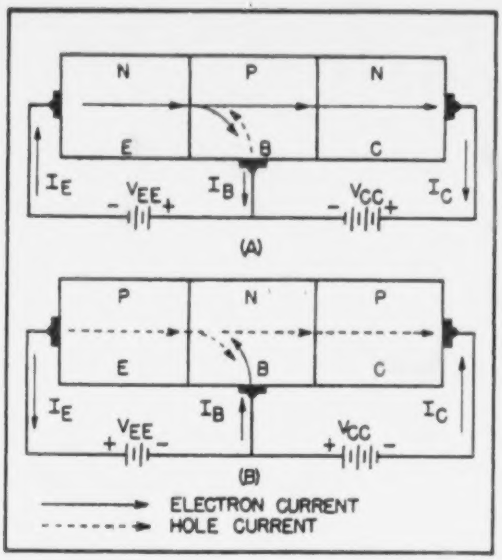

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Figure 1-20. Bias current paths for transistors.

terminal. They will then move out of the collector and return to the positive terminal of V_{CC} as collector current (I_C).

The bias current paths in a PNP transistor are shown in figure 1-20, B. The majority current carrier in the PNP transistor is the hole. Briefly, the method of transporting current through a PNP transistor is as follows: The energy supplied by the emitter supply (V_{EE}) causes an electron-hole pair to be generated at the emitter terminal. The electron travels through the wire to the positive terminal of V_{EE} as emitter current (I_E). The hole travels through the transistor from emitter to collector. Upon reaching the collector terminal, the hole will recombine with an electron from the negative terminal of the collector supply (V_{CC}).

While the current flow in the external circuit of the PNP transistor is opposite to that of the NPN, notice that, regardless of the type of transistor, the majority carrier always moves through the transistor from the emitter to collector.

Some holes, which are injected into the base by the emitter, will recombine with electrons in the base. This recombination causes electrons to be drawn from the negative terminal of V_{EE}, through the base lead, into the N-type base material. The result is a small base lead current (I_B).

Exercises (209):

1. Name the parts of a transistor and state job of each.

2. Name the classes of transistors.

3. How are NPN and PNP transistors formed?

4. Explain how the two junctions of a transistor are biased in normal operation.

5. Explain what happens to some of the electrons that move into the base region in an NPN transistor under normal operation.

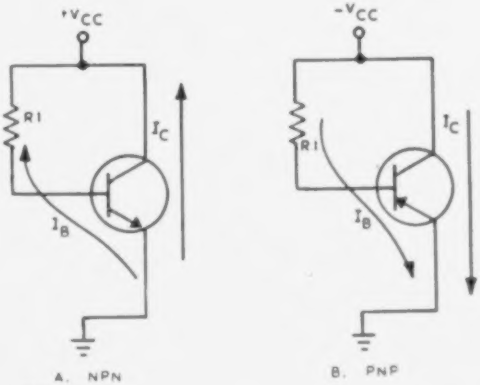
6. Briefly explain the current path in an NPN transistor when the correct bias is applied.

7. Current flow in the external circuit of the PNP transistor is the ____________ to current flow of the NPN transistor.

210. Differentiate between the three types of transistor amplifiers.

Transistor Symbols. The only difference between the PNP and NPN symbols is the direction of the arrow on the emitter lead. In the PNP, the arrow is pointing toward the base lead. Current flows against the arrow as in P–N diodes. The external current in a PNP transistor is into the collector and out of the emitter. External current in an NPN transistor is into the emitter and out of the collector. In either case, the external current flows against the arrow on the emitter lead. The base emitter junctions have forward bias and the collection-base junctions have reverse bias.

Transistor Configurations. A transistor may be connected in any one of the three basic configurations.



C182-56

Figure 1-21. Grounded-emitter configuration.

These circuits are common-emitter, common-base, and common-collector. They are also called grounded-emitter, grounded-base, and grounded-collector. The common or grounded element is that element which is common to both the input and the output circuit. We will discuss DC or static operation of the three transistor configurations.

Grounded-emitter configuration. Figure 1-21 illustrates the connections for both NPN and PNP transistors for a grounded emitter. The NPN transistor has a positive voltage ($+V_{CC}$), and the PNP transistor has a negative voltage ($-V_{CC}$) to satisfy the requirement for reverse bias between the collector and base. The forward bias for the emitter-base junction is provided by V_{CC} and R1 in series with the base-emitter junction. In both cases, the emitter of the transistor is grounded.

With forward bias applied, there are two direct current paths in these circuits. Figure 1-21, A, shows a path from ground into the emitter, out of the base lead, and through R1 to the positive V_{CC}.

Figure 1-21,B, shows current paths for the PNP transistor. Notice that V_{CC} is now negative, and the current flows from the power source to ground. The characteristics of the grounded-emitter junction amplifier can be summarized by the following list of major features. There is a signal-voltage phase reversal between the input and output. The grounded emitter has the highest current gain factor of the three basic connections. It also has a moderate input impedance and a moderate value of output impedance. It has a comparatively low response to high frequencies and high values of power gain.

Grounded-base configuration. Figure 1-22 illustrates PNP and NPN transistors biased for operation in a grounded-base arrangement. The NPN transistor has a positive V_{CC} source voltage which established the required reverse bias between the collector and base. The forward bias for the base-emitter junction is furnished by the $-V_{EE}$ source voltage. V_{CC} is about 10 volts and V_{EE} is in the tenths of volts range. For the NPN transistor, current will leave the $-V_{EE}$ terminal and flow into the emitter. Part of this current leaves the base lead as base current I_B, and the remaining current leaves the collector lead as collector current I_C. Characteristics of the grounded-base configuration are low-input impedance, high-output impendance, no voltage-phase reversal between input and output, average current gain of less than unity, good stability, and moderate power gain.

The PNP transistor has a $-V_{CC}$ for the reverse bias between collector and base, and a $+V_{EE}$ for the forward bias between the base and emitter. Current flows into the collector and base leads and out of the emitter lead.

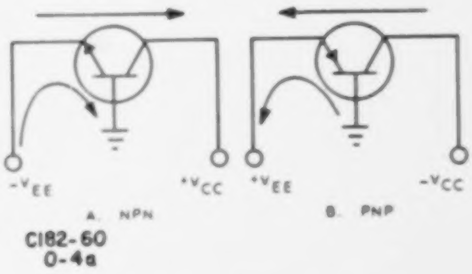


Figure 1-22. Grounded-base configuration.

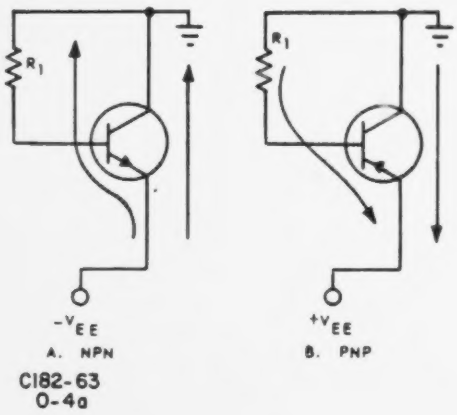


Figure 1-23. Grounded-collector configuration.

Grounded-collector configuration. Figure 1-23 shows the collector grounded and proper bias, with the resulting paths. One path is from ground through the emitter-to-base junctions and through R1; and the other path is the emitter-collector current.

The common collector configuration is also called an emitter follower. Base current controls emitter current. The main characteristics of the common collector transistor are: low-output impedance; high input impedance; moderate-to-high power gain; a voltage gain of less than unity; and no signal voltage phase reversal between input and output.

The three transistor-amplifier configurations are shown in figure 1-24 with their input and output signals. Note that in the grounded emitter, part A of figure 1-24, the input and output signals have a 180-degree phase shift. The grounded base, part B, and the grounded collector, part C, have their signals in phase.

Exercises (210):

1. What is the direction of external current flow in a transistor?

2. In what direction would the arrow point in a PNP transistor symbol?

3. In what direction would the arrow point in a NPN transistor symbol?

4. What are the three basic transistor configurations?

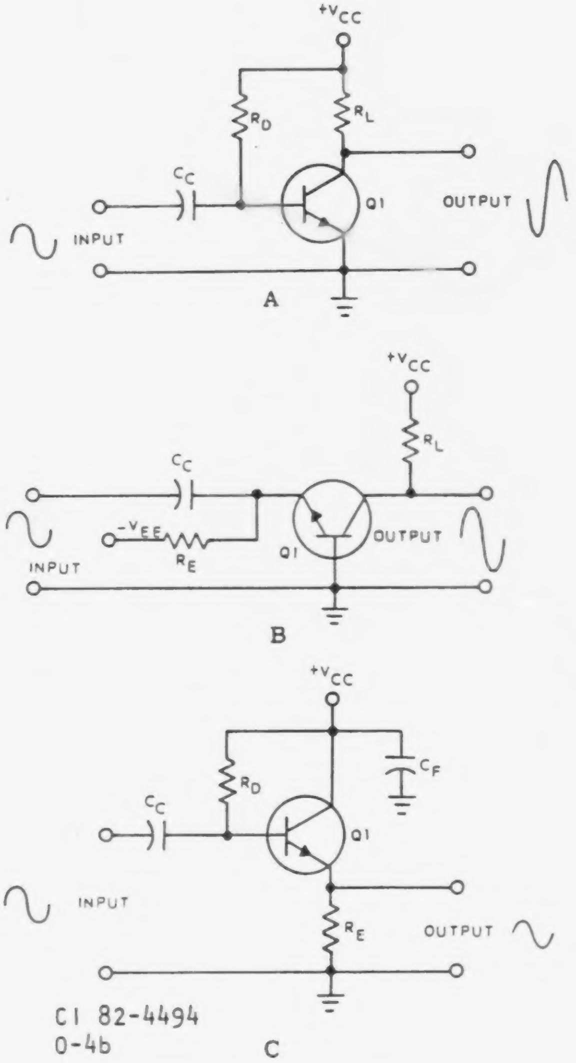


Figure 1-24. Transistor amplifiers.

5. What is the phase of the input compared to the output of a common emitter?

6. What is the current gain of a common emitter transistor circuit?

7. What is the response of the common emitter to high frequencies?

8. Give the direction of current flow in the common base transistor.

9. What is the common collector configuration also called?

10. What is the signal voltage phase reversal between input and output of a common collector?

11. What is the input and output impedance of a common collector transistor configuration?

211. Identify a DC-power supply; state its physical makeup and the important factors to consider in its application.

Power Supplies. Electronic circuits that contain transistors require various values of DC voltage for their operation. Batteries are suitable for supplying these voltages for some portable equipment, but a DC-power supply is required for systems that are operated frequently or for prolonged periods of time. The elements commonly found in DC-power supplies are an AC source, transformer, rectifier, filter, voltage divider, and voltage regulator. All power supplies do not contain all six of those elements. The only essential parts are the AC source and a rectifier; however, most power supplies use filters. Many power supplies for transistorized AC circuits contain only these three elements.

The other elements mentioned contribute to the ability of the power supply to provide a wider range of output voltage, voltages that are smoother, or voltages that are more stable.

Rectifiers. Semiconductors are coming more and more into use in DC-power supplies. The reasons for this use of semiconductors are as follows: (1) no requirement for filament power (with bulky and heavy filament transformers), (2) immediate operation with no warmup time, (3) low internal voltage drop that is relatively independent of load current, (4) low-operating temperature, and (5) small physical size.

The single-phase, half-wave rectifier is the simplest type of rectifier circuit. It consist of a diode in series with the AC source and the load. Figure 1-25 shows four basic arrangements for a half-wave rectifier. Parts A and B show the use of a transformer for the AC source. The transformer is to isolate or to step up the voltage for a higher output voltage. The isolation transformer permits either end of the ouput DC supply to be grounded so that the polarity of the output voltage is determined by the end of the output that is

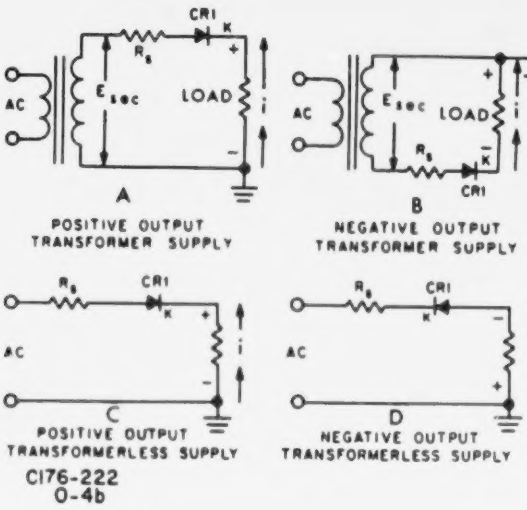

CR1
K
R_s
E_{sec}
LOAD
AC
i
A
POSITIVE OUTPUT TRANSFORMER SUPPLY
B
NEGATIVE OUTPUT TRANSFORMER SUPPLY
C
POSITIVE OUTPUT TRANSFORMERLESS SUPPLY
D
NEGATIVE OUTPUT TRANSFORMERLESS SUPPLY
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Figure 1–25. Basic half-wave rectifier circuit.

grounded. The two-circuit variations shown in parts C and D of figure 1-25 operate directly from the AC source. In this case, the terminal of the AC source that is grounded must also be grounded in the DC supply.

The diode is the same in all four circuits. The direction of current flow through the diode and the location of the ground terminal determine whether the DC output is positive or negative. Electron-current flow is always against the arrow of a semiconductor diode rectifier.

Figure 1-26 shows the operation of a half-wave rectifier. The rectifier circuit is shown in parts A and B, and the waveforms are shown in part C. When the AC-input voltage (top of part C) is in its positive alternation, the polarity at the input of the rectifier is as shown in the rectifier current waveform, and the current flows through the load as shown by the DC-load voltage waveform. During the negative alternation, the polarity of the input to the input rectifier is as shown in part B. A small amount of reverse current flows through a semiconductor as seen in the rectifier current waveform. This does not show up as an output in the DC-load voltage waveform because the impedance of the rectifier is so much larger than the load impedance during reverse bias that, for all practical purposes, all the voltage is dropped across the rectifier. The resistor R_s shown in all the rectifiers in figures 1-25 and 1-26 is called a *surge resistor*. It limits the peak current through the rectifier to a safe value. The resistor may not be needed if the rectifier has a transformer-input or a choke-input filter.

The half-wave rectifier produces an output voltage as shown in part C of figure 1-26. The frequency of this voltage is the same as the input voltage and requires filtering to smooth out the ripple and produce a steady DC voltage. Assuming that the output is filtered, the peak inverse voltage across the diode in a half-wave rectifier is approximately 2.83 times the RMS value of the applied (or transformer secondary) voltage.

The full-wave rectifier is one of the most common types of rectifier circuits used in electronic equipment. It is used in both low-voltage and high-voltage applications. The full-wave rectifier consists of a transformer with a center-tapped secondary windings at least two diodes, and a load. At least one diode is connected at each end of the secondary winding, as shown in figure 1-27. The load is connected between the transformer center tap and the common junction of the two diodes. The diodes conduct on alternate half-cycles of the AC-input voltage in the secondary of T_1 as shown in figure 1-27. The dashed arrows show the conduction of CR_1, and the solid line shows the current path for the conduction of CR_2. The current wave shape for each of the diodes is shown in part B of figure 1-27. Notice that current flows in only half of the transformer secondary at any one time and that current flow through the load is in the same direction all the time.

The full-wave rectifier circuit uses the transformer for a greater percentage of the time than does a half-wave rectifier, and there are two pulsations of current in the load for each complete cycle of applied voltage, as shown by the DC load voltage wave shapes in figure 1-27. Since only half of the secondary windings is in use at any one time, the secondary voltage must be twice as much as the half-wave rectifier in order to get the same power supply output voltage. However, the full-wave rectifier is more efficient since the transformer is in use all the time and there is less

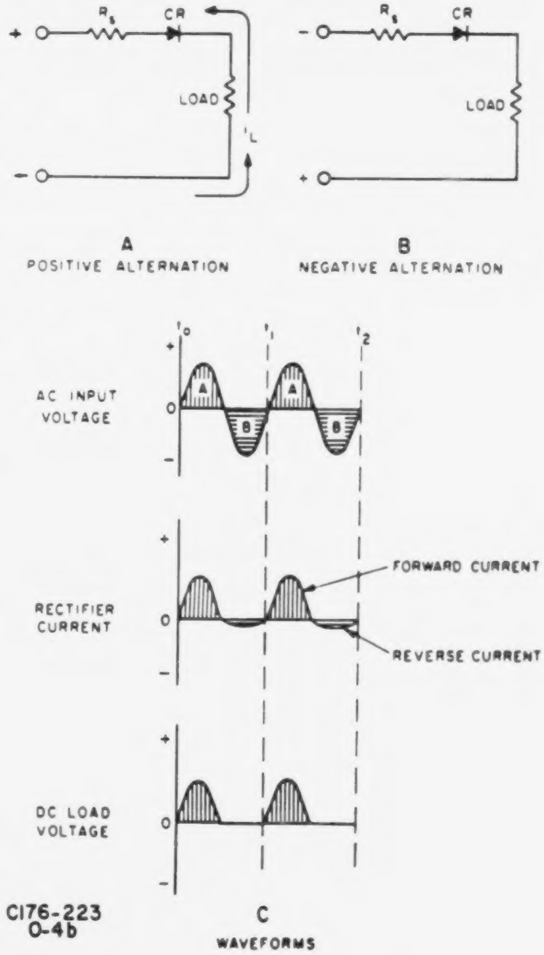

Figure 1–26. Half-wave rectifier operation.

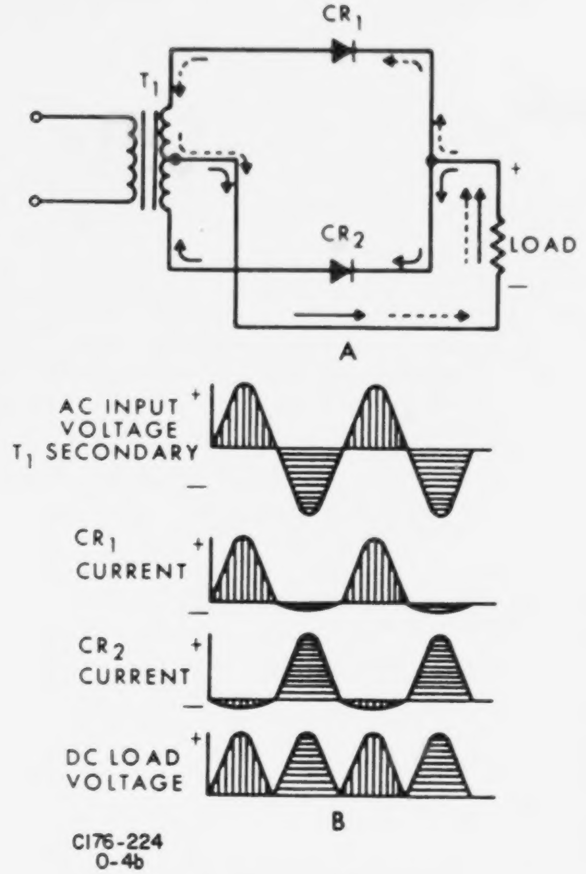

Figure 1–27. Full-wave rectifier operation.

output ripple. This gives the full-wave rectifier better voltage regulation than a half-wave rectifier. With a filter, the peak inverse voltage across a diode in a full-wave rectifier circuit is approximately 2.83 times the voltage across half of the transformer secondary or approximately 1.41 times the voltage across the entire secondary.

In a full-wave rectifier circuit designed for high-voltage output, the peak inverse-voltage rating of the semiconductor diode is an important consideration. For this reason, several diodes are sometimes placed in parallel to obtain a higher current output from a power supply.

Exercises (211):

1. What are the essential items needed for a DC-power supply to operate?

2. What is the simplest type of rectifier?

3. In a half-wave rectifier, what does the direction of current flow through the diode and location of the ground determine?

4. What is used to produce a steady DC output of a half-wave rectifier?

5. What is the minimum amount of diodes that can be used in a full-wave rectifier?

6. What is an important factor to consider when a full-wave rectifier circuit is designed for peak-voltage output?

212. State operational characteristics of electronic voltage regulators.

Electronic Voltage Regulator (EVR). An electronic voltage regulator is a circuit designed to maintain the output voltage nearly constant regardless of input voltage or load changes. An electronic voltage regulator can be likened to the series resistive circuit shown in figure 1-28. The load resistance is connected in series with variable resistor R1 across the output terminals of the power supply. The voltage from the power supply has ripple and is not regulated. Further, the resistance of the load may change. Due to input voltage and load resistance changes, the voltage across the load cannot remain constant.

However, if the size of R1 is increased as the input voltage goes up, the voltage across the load can be made to remain constant. An increase in E applied to a series circuit increases I total. A corresponding increase in R total will decrease I total back to its original value. Further, if the size of R1 is decreased as the input voltage decreases, the output voltage remains constant. Likewise, if the load resistance is decreased and if R1 is decreased a proportional amount, the load voltage remains constant. If the load resistance increases and if R1 is increased a proportional amount, the load voltage remains constant. This is the basic principle of an electronic voltage regulator circuit.

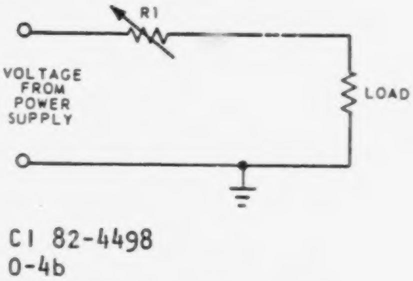

Figure 1–28. Equivalent EVR circuit.

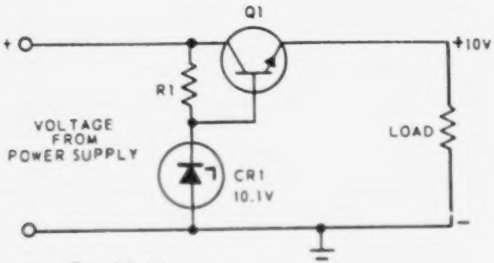

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Figure 1-29. Simplified EVR circuit.

A simplified electronic voltage regulator circuit is shown in figure 1-29. A transistor has been inserted in place of the variable resistor. Recall that a transistor is a variable resistance, and its resistance can be electronically controlled. Zener diode regulator CR1 with current limiting resistor R1 develops forward bias for Q1. The zener is rated at 10.1 volts and, during normal operation, holds the voltage on the base of Q1 constant at this value. With Q1 conducting, a voltage of approximately 10 volts is developed across the load resistance. Therefore, the bias on Q1 during normal operation is the difference between the base-emitter voltages, or .1 volt. With the base voltage of Q1 held constant by CR1, the only way the bias of Q1 can be changed is for the voltage on the emitter to change. Thus, the voltge on the emitter, which is also the load voltage, determines the resistance of Q1.

If, for any reason, the load voltage decreases, the bias on Q1 increases. With an increase in forward bias, the resistance of Q1 decreases and more current flows, bringing the load voltage back toward its original value.

Or, if the load voltage increases, the bias on Q1 decreases. A decrease in forward bias of Q1 causes resistance of Q1 to increase. This causes less current to flow, and the voltage across the load returns to the regulated value. The circuit is designed so that the resistance change in Q1 is proportional to a change in load voltage. This operation holds the voltage across the load relatively constant in case either the input voltage or the load resistance changes.

Although this is an improvement over the simple zener diode regulator, the simplified electronic voltage regulator still has limitations. Figure 1-30 shows a schematic of a complete electronic voltage regulator circuit. Now, two class A amplifiers, Q1 in series and Q2 in shunt, detect and compensate for variations in source voltage or load. With the addition of Q2 and voltage divider network (R3, R4, and R5), this circuit regulates the voltage across the load to a smoother, more constant value.

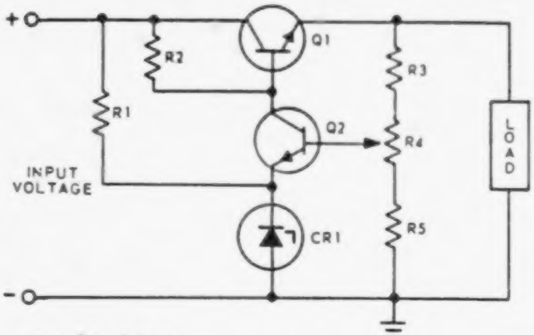
Transistor Q1 is in series with the load. The action of Q1 changing its resistance to hold the output voltage constant is still present. Notice that the base current of Q1 is now controlled by Q2. R2 is the collector-load resistor for Q2, and the forward bias resistor of Q1. Resistor R1 is the current limiting resistor for CR1.

The bias for transistor Q2 is determined by the voltages on its emitter and base. The zener diode sets the emitter voltage, which is called the Q2 reference voltage. The voltage on the base of Q2 is developed by the voltage divided network (R3, R4, and R5) connected across the load. This arrangement continuously samples the output voltage. In other words, if the output voltage were to increase, the voltage on the moveable arm of R4 would increase. So, with the emitter voltage of Q2 being held constant at all times, the conduction of Q2 is controlled by the voltage at the arm of R4.

To illustrate the operation of the electronic voltage regulator, let's discuss (1) an increase of input voltage and (2) an increase in the load on the circuit. An increase in input voltage is felt across voltage dividers R3, R4, and R5. The voltage at the arm of R4 will go in a positive direction. This increase in voltage at the base of Q2 increases its forward bias. Transistor Q2 conducts harder and increases the voltage drop across R2. This makes the voltage on the base of Q1 less positive. A less positive voltage on the base of Q1 decreases the forward bias of Q1, which increases its resistance. When the resistance of Q1 increases, more voltage is dropped across Q1 (collector-to-emitter). The increase in voltage drop across Q1 nearly equals the increase in input voltage (from the filter), and the load voltage remains relatively constant. This action is instantaneous, and the EVR circuit maintains a regulated output voltage any time the input voltage increases. A decrease in input voltage results in just the opposite action within the circuit, and the output voltage remains at the regulated value.

An increase in load on the circuit means that the resistance of the load has decreased. When this occurs, load voltage decreases. Any change in load voltage causes the voltage at the arm of R4 to decrease. The decrease in voltage at the base of Q2 reduces its forward bias. Transistor Q2 then conducts less, and the current through the load resistor decreases. This causes the voltage on the base of Q1 to increase (become more positive). The increase in voltage on the base of Q1 increases forward bias and causes the resistance of Q1 to decrease. The decrease in resistance of Q1 (emitter-to-collector) causes the voltage across Q1 to decrease, leaving more voltage across the load. The decrease in voltage across Q1 nearly equals the decrease in load voltage and, for all practical purposes, the load voltage remains constant.

Transistor Q1 is referred to as the series regulator. The voltage on the arm of R4 is called the error signal, and Q2 is the differential or error amplifier, since it amplifies the



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0-4b

Figure 1-30. Electronic voltage regulator.

error signal. The zener diode provides the reference voltage for error amplifier Q2. This regulator circuit provides very close regulation of the output voltage.

Another characteristic of the electronic voltage regulator circuit is that the output voltage can be adjusted to a specific value. Resistor R4 is the output voltage adjuster. If the arm of R4 is moved up, the forward bias on Q2 increases, and Q2 conducts harder. The voltage across R2 increases, and the voltage on the base of Q1 decreases. The forward bias of Q1 is thus decreased, so the resistance of Q1 increases. This action will reduce the output voltage.

If the arm of R4 is moved down, the forward bias of Q2 decreases. Q2 conducts less, and the voltage across R2 decreases. The voltage on the base of Q1 increases, which decreases the resistance of Q1. This action will cause the output voltage to increase to a higher value.

As with any electronic circuit, the EVR is subject to failure. Knowing the correct operation and the symptoms of malfunction, a technician can repair an electronic voltage regulator circuit very rapidly.

Two quick checks can be made to determine the possible trouble. First, check the DC (load) output voltage and, second, check to see if the circuit still regulates the output voltage.

Assume that the output voltage is higher than normal and that there is no regulation. This could be caused by an open zener diode. With CR1 open, Q2 cannot conduct; and the voltage on the base of Q1 may be very high. The resistance of Q1 will be very low; therefore, the output voltage will be higher than normal. The circuit cannot regulate because the reference voltage for Q2 is no longer present. Another possibility is R3 is open. With R3 open, the voltage on the base of Q2 will be near zero volts, and Q2 cannot conduct. Again, the voltage on the base of Q1 will be a high positive, and the output voltage will rise to a value higher than normal. The circuit cannot regulate because the sample voltage is no longer present. If transistor Q1 were to short, the same symptoms would be present.

A symptom of no output voltage could be caused by an open Q1 or an open R2. With Q1 open, the series circuit is broken. With R2 open, there is no forward bias for Q1, so the only output voltage will be due to minority current.

Exercises (212):

1. In figure 1-29, what happens to the bias on Q1 if the load voltage increases?

2. In figure 1-30, what is the function of the zener diode?

3. In figure 1-30, how is the conduction of Q2 controlled?

1-4. Diagrams and Schematics

For you to troubleshoot the aircraft electrical systems, you will have to know how to use wiring diagrams and schematics. The format for these will vary with different aircraft. The maintenance instructions for the aircraft has detailed information on how to use the diagrams and schematics for that aircraft. Schematics usually show the internal wiring of the components in a system. Wiring diagrams will show each wire segment and other useful information about a circuit. Schematics can be a big help in understanding how a system works, but make sure you always use the proper wiring diagram when troubleshooting.

213. Draw the symbols used in circuit schematics.

Basic Circuit Symbols and Components. Symbols are used to represent various electrical and electronic components and wires.

Let's examine a few basic circuit symbols. Refer to each symbol in figure 1-31 as we describe each component.

a. Resistors. There are several varieties of resistors. The first resistor is the most common and comes in a wide range of ohmic values. The rheostat is a type of variable resistor. It is usually wire-wound and is available only in low-ohmic values. Another wire-wound device is the tapped resistor. Different amounts of opposition are sensed at its various taps. The potentiometer is either made of carbon or wire-wound. This variable resistor is also available in a wide range of ohmic values.

b. Battery. A device that converts chemical energy to electrical energy. In the single or multicell battery, the short line represents the negative terminal and the longer line represents the positive terminal. The negative terminal of one cell is connected to the positive terminal of another cell, and so on.

c. Ground. A ground is a point in a circuit used as a common reference point from which voltages are measured. Voltages may be either positive or negative with respect to ground. You are probably familiar with the electrical ground on an automobile; the chassis is the common reference point.

d. Voltmeter. This component is used to measure voltage in volts.

e. Ammeter. An ammeter is used to measure current flow in amps.

f. Ohmmeter. An ohmmeter is used to measure resistance in ohms.

g. Rotating machines. A generator is used to convert mechanical energy to electrical energy. A motor is used to convert electrical energy to mechanical energy.

h. Switches. A switch is used as a circuit-controlling device or simply a means of turning the circuit power ON and OFF. There are numerous switch combinations that you will learn by association. The three illustrated here include the following: SPST which means single-pole, single-throw; SPDT which means single-pole, double-throw; and DPDT which means double-pole, double-throw.

i. Lamp. A lamp can be used in a circuit as a loading device or to indicate a circuit condition.

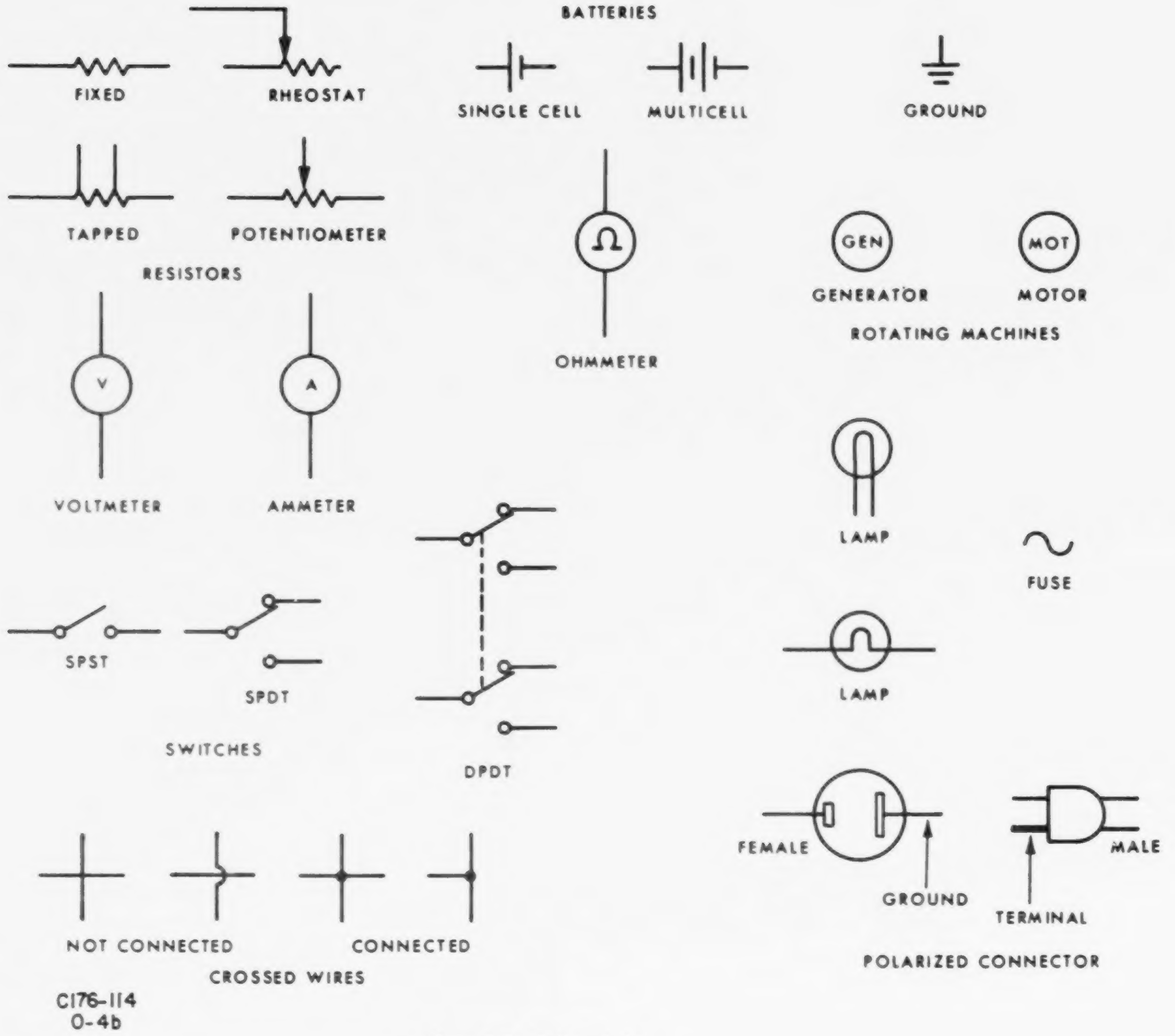

BATTERIES
FIXED
RHEOSTAT
SINGLE CELL
MULTICELL
GROUND
TAPPED
POTENTIOMETER
RESISTORS
Ω
OHMMETER
GEN
GENERATOR
MOT
MOTOR
ROTATING MACHINES
V
VOLTMETER
A
AMMETER
LAMP
FUSE
LAMP
SPST
SPDT
SWITCHES
DPDT
FEMALE
GROUND
TERMINAL
MALE
POLARIZED CONNECTOR
NOT CONNECTED
CONNECTED
CROSSED WIRES
C176-114
0-4b

Figure 1-31. Basic symbols.

j. Fuse. A fuse is used as a protective device for the circuit in which it's located.

k. Crossed wires. To indicate that crossed wires do not connect, a dot is not placed at the junction where the wires cross. Some schematics may still use the older system of "hooking" one wire over the other to indicate the lack of a connection. Connected wires are shown by placing a dot at the junction where the wires cross.

l. Polarized connectors. This unit is used in conjunction with DC or AC circuits. In either case, the larger terminal on the male plug or the larger opening in the female plug is always the grounded terminal.

Exercises (213):

1. Draw the schematic symbols for the following:
   a. Ground.
   b. Rheostat.
   c. Ammeter.
   d. Battery.
   e. Crossed wires not connected.
   f. Lamp.

g. SPDT switch.

h. Fuse.

i. Ohmmeter.

j. Fixed resistor.

k. Voltmeter.

l. Tapped resistor.

m. Crossed wires connected.

n. Motor.

214. State procedures for troubleshooting parallel and series-parallel circuits.

Troubleshooting Parallel Resistive Circuits. Troubleshooting parallel circuits follows the same applied practical techniques you use in troubleshooting almost any electrical circuit. Use the ammeter-voltmeter-ohmmeter functions of your multimeter to help you in locating a defective component. The only difference in troubleshooting a parallel circuit when compared with a series circuit is the way you apply the techniques of troubleshooting. For example, if a component in a series circuit is open, no circuit current is indicated. This indication is not true with respect to a parallel circuit. If a component in a parallel circuit is open, there will be a decrease in circuit current.

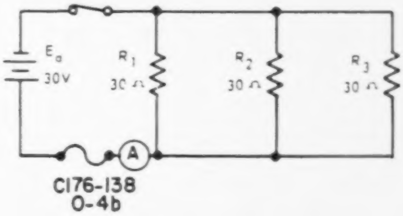


Figure 1–32. Parallel-circuit troubleshooting.

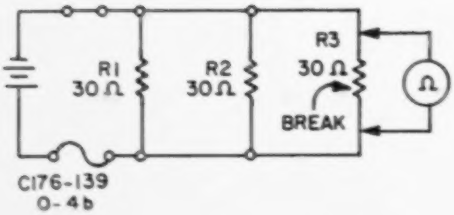


Figure 1–33. Parallel-circuit continuity.

In the parallel circuit shown in figure 1-32, let's examine the affect an open resistor has on circuit operation. For ease of explanation, we have used three resistors of equal size. Let's assume that resistor R_3 is open. Unlike a series circuit, current continues to flow through the good components in a parallel circuit. However, current ceases to flow through the open component. Also unlike the series circuit, an open component in this type of circuit cannot be detected with a voltmeter. The quickest way to detect an open component or resistor in this case is with the use of an ammeter or ohmmeter. Before going any further, let's calculate the total resistance, total current, and individual branch currents when the circuit is trouble-free. Using methods discussed in a previous section, you will find that the total resistance is 10 ohms and the total current flow is 3 amps.

Now that we know what the total current and branch currents are supposed to be, let's insert an ammeter into the circuit as shown in figure 1-33. At this point in the circuit, the ammeter should read the total current, 3 amps. However, let's assume that the meter reads 2 amps. Since we know the branch current is supposed to be 1 amp in each branch, it is obvious that one branch must be open. Thus, we should insert an ammeter into each branch at a point just below the resistor. The branch showing zero current flow is open.

Another way to locate this same trouble is with the use of an ohmmeter. If, after disconnecting the power source, an ohmmeter is connected across R_3, as shown in figure 1-33, we would obtain a reading which would be misleading. Although R_3 is open, the ohmmeter will still measure the resistance of R_1 and R_2 in parallel. Two 30-ohm resistors in parallel would give us an equivalent resistance of 15 ohms.

To accurately determine the condition of R_3 with the use of an ohmmeter, we must disconnect the defective component from the remaining circuits. In this manner, the resistor being checked (R_3, in our case) is not shunted or paralleled by R_1 and R_2 As we have previously stated, R_3 is open; thus, the reading on the ohmmeter would indicate an infinite resistance.

In a series circuit, a voltmeter is often used as an aid in locating a defective component such as an open resistor. A voltmeter reads the applied voltage when it is placed across an open circuit. This technique cannot be followed in troubleshooting a simple parallel circuit. Refer to figure 1-33. We know that resistor R_3 is open. If we place a voltmeter across R, it would read the applied voltage of 30V. If we place a voltmeter across R_1 and R_2, it would also read the applied voltage. When a voltmeter is placed across a good component or an open component in a simple parallel circuit, the voltmeter still reads the applied voltage. It follows then that, in troubleshooting a parallel circuit, you should not rely upon the use of a voltmeter to locate a defective component.

Thus far, we have been discussing troubleshooting parallel circuits with respect to open components. Let's see what effect a shorted component has on a parallel circuit. Assume R_1 is shorted. This condition would present the current a path of negligible resistance. Since current always takes the path of least resistance, the total current would flow through the short.

Another way to look at the circuit with R_1 shorted is just like connecting the two terminals of the 30-volt battery together. In either case, current rises to an excessive value and the fuse would burn out. Once the fuse has blown, the total circuit current ceases to flow and the applied voltage would no longer be felt across R_1 or R_2.

Since a shorted component usually means a blown fuse, troubleshooting with an ammeter or voltmeter becomes difficult. However, we still have the ohmmeter as an aid in locating the defective component. As in the case of troubleshooting for an open resistor in a parallel circuit, a shorted resistor can be detected with an ohmmeter only if one end is disconnected. A shorted resistor will give a reading of zero ohms on the ohmmeter.

Troubleshooting Series-Parallel Circuits. Troubleshooting a series-parallel resistive circuit is quite similar to troubleshooting a series or parallel-resistive circuit. Two troubles you will encounter in a series-parallel circuit are our old enemies—the open and the short. First, let's see what effect an open has on a series-parallel circuit by using figure 1-34.

Circuit analysis. Assume that an open occurs in the series portion (R_1) of the circuit; current flow in the entire circuit will stop. In this case, the entire circuit will cease to function. If an open occurs in either of the parallel branches (R_2 or R_3) of the circuit, the remaining portion of the circuit will continue to function. Analyzing the circuit tells us that, with either (but not both) parallel resistor open, the circuit becomes a simple series circuit. With either parallel resistor open, total resistance increases and total current decreases. A decrease in total current results in a decrease in voltage drop across R_1. If the voltage drop across R_1 decreases, then, by Kirchhoff's Law, the voltage drop across the remaining good parallel resistor must have increased. If an open occurs in R_3, current through the series portion of the circuit will continue to flow. This will cause an increase in voltage across R_2.

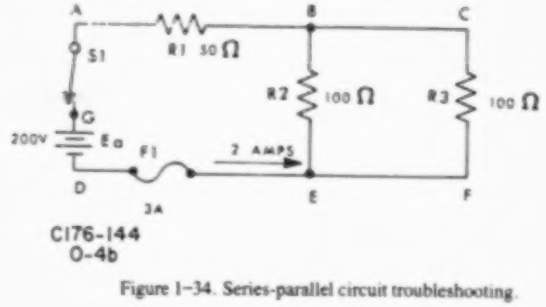


Figure 1–34. Series-parallel circuit troubleshooting.

A short in the series portion of a series-parallel circuit will cause a decrease in total resistance. This, in turn, will cause the total current to increase. Let's again examine the circuit as shown in figure 1-34.

Since R_1 is 50 ohms and the equivalent resistance of R_2 and R_3 is 50 ohms, the total resistance is 100 ohms. The total current is 2 amps. If R_1 became shorted, the total resistance would decrease to 50 ohms and the total current would increase to 4 amps. This increase in current would be sufficient to blow the 3-amp fuse. The same thing would occur in the circuit if either R_2 or R_3 became shorted. The total resistance in the circuit would be 50 ohms, the value of the series resistor only.

Troubleshooting with a voltmeter. Another approach to troubleshooting a circuit is with the use of a voltmeter or ohmmeter. However, troubleshooting series-parallel circuits with a voltmeter can be very difficult unless there are some knowns to be used as references. If component sizes and the applied voltage are known, with a little mathematical computation, troubleshooting can be done with accuracy.

To troubleshoot the circuit in figure 1-34, we must make certain assumptions. The first assumption is that all components are good, except the one checked. These are some indications that can be expected when the voltmeter is placed across each component. For example, if the voltmeter is placed across an open switch, you will read the applied voltage. If the switch is shorted, you will read zero volts on the voltmeter. Likewise, if the switch is good, you will read zero volts. However, a reading across an open-series resistor will give you the applied voltage reading.

Like an open, a short can be detected with a voltmeter. Let's examine the circuit again in figure 1-34. Placing the voltmeter across points A and B would indicate the condition of R_1. If R_1 is shorted, no voltage would be indicated between these points. If R_1 is good, then the voltage drop of R_1 would be read.

An indication of a short in the parallel portion of the circuit may be obtained with a voltmeter, but the particular defective branch cannot be determined. By connecting the voltmeter across points B and E, the parallel combination can be checked. If one of the resistors in the parallel combination is shorted, the reading between points B and E and points C and F will be zero. To determine which resistor is shorted, either R_2 or R_3 will have to be disconnected from the circuit and checked with an ohmmeter.

Troubleshooting with an ohmmeter. This procedure can be accomplished in a similar manner as when using a voltmeter. Remember, though, whenever you troubleshoot with an ohmmeter, the power must first be removed from the circuit. Let's again refer to figure 1-34 and assume that switch S_1 is open to remove the source voltage from the circuit. By placing the meter across points A and B, you can check the circuit between these points for continuity. If resistor $R1_1$ is open, a reading of infinite resistance will be obtained on the meter. If it is good, the value of the resistor will be indicated on the meter.

Like the voltmeter, the ohmmeter can give misleading indications in the parallel portion of the circuit. In order to check the circuit between points B and E, one of these points will have to be broken (disconnected).

Troubleshooting for a short with the ohmmeter is an identical process of that of troubleshooting an open. The only difference will be in the reading obtained on the meter. When the ohmmeter is connected across a shorted component, a reading of zero will be indicated.

Exercises (214):

1. When troubleshooting a resistive parallel DC circuit, you find the current has decreased. What would be a probable cause?

2. In troubleshooting the circuit in exercise 1, what reading will you get when you place an ammeter in the branch containing the open resistor?

3. Why must a defective component be disconnected from the remaining circuit when using an ohmmeter to determine its condition?

4. In a parallel circuit that contains three branch resistors, if one resistor suddenly shorts, how are circuit operations affected?

5. How is current flow affected if an open occurs in the series portion of a series-parallel circuit?

6. How is current flow affected if a short occurs in the series portion of a series-parallel circuit?

7. If an open occurs in the parallel portion of a series-parallel circuit, how is the voltage drop across the series resistor affected?

8. If a short occurs in the parallel portion of a series-parallel circuit, what will the reading be?

9. If a voltmeter is connected across a good series resistor in a series-parallel circuit, what will the reading be?

10. What precautionary step must you take before connecting an ohmmeter into an electrical circuit?

11. What is the meter reading on an ohmmeter connected across a shorted component?

Test Equipment

IN THE FIELD of electricity, accurate measurements are essential. You, as an aircraft electrical systems specialist, will be working with ammeters, voltmeters, ohmmeters, and special test equipment that will be covered as we progress through this course. To properly use and understand the various items of test equipment, it is important that you have a good understanding of their care and operation. In your work, you use the following equipment to determine if the circuits of a system or a system component are operating properly:

- An ammeter to measure the amount of current flowing in a circuit.
- A voltmeter to determine the voltage existing between two points in a circuit.
- An ohmmeter or a megger (megohmmeter) to measure circuit continuity and total or partial circuit resistance.

You may also find it necessary to determine the total power being consumed by certain equipment; in such a case, you will have to use a wattmeter. For measuring other quantities, such as power factor and frequency, you will need to use still other types of electrical instruments.

In each case, the instrument indicates the value of the quantity measured, and you interpret this information to understand the way the system or component is operating.

Let us point out again that, as an aircraft electrician, you need a thorough understanding of the operation and limitations of various types of electrical measuring equipment, coupled with the theory of circuit operation. This is most essential in troubleshooting, servicing, and maintaining electrical systems and equipment.

2-1. Meters and Testers

Electrical quantities are measured by meters that indicate values in terms of a specific unit on a calibrated scale. Due to the variations in tasks, different sensitivity qualities are built into the various meters.

Testers are built to test specific equipment or systems. If you use meters and testers correctly, your job will be made easier. We will start our discussion with the Tektronix 453 oscilloscope.

215. Specify the power requirements and the type of probes used on the Tektronix 453 oscilloscope.

Applying Power. One of the most important considerations prior to using the 453 is to insure that the oscilloscope is connected properly to the correct voltage source. The reason for this is safety for both you and the instrument. Connecting the 453 to the proper voltage source insures that the instrument will work properly and will not be damaged. Grounding the case of the oscilloscope to a known ground enables you to use the 453 or any other oscilloscope safely.

Power requirements. The Type 453 can be operated from either a 115- or 230-volt, 50–400 Hz nominal line. Switching between ranges is automatically accomplished when the correct power cord for the nominal voltage range is installed in the power receptacles on the rear of the instrument. You can see this difference in the power receptacles on the rear panel by referring to figure 2-1,C. Even though these two differently shaped power receptacles on the rear panel insure a proper connection at the oscilloscope, you should make sure that the voltage source that you are plugging the oscilloscope into is of the correct value.

Range switch. In addition to the power receptacles on the rear panel, there is a HIGH-LOW voltage selector switch. This switch is positioned by you, the operator, according to the actual value of the 115- or 230-volt source. for example, the actual value of a 115-volt source may range as much as ±20 volts (95 volts to 135 volts) or greater. If the input voltage is between 96–127 volts for a 115-volt source or between 192–254 volts for a 230-volt source, the LOW range is selected. The HIGH position is selected when the input voltage is between 103–137 volts for a 115-volt source or between 206–274 volts for a 230-volt source. It should be noted that the LOW and HIGH range for each category overlap. The correct procedure would be to position the range switch according to the following conditions:

a. For a 115-volt source:

(1) Use the LOW range for 102 volts or lower.
(2) Use the HIGH range for 103 volts or higher.

b. For a 230-volt source:

(1) Use the LOW range for 205 volts or lower.
(2) Use the HIGH range for 206 volts or higher.

Use of Probes. Now that you have applied power and grounded the oscilloscope, you are ready to connect the oscilloscope to a signal. This signal may be the output of an amplifier that you want to check for the amount of amplitude and to see if the output is distorted. To connect the oscilloscope to the test signal you must use some type of probe.

Types of probes. There are mainly four types of probes:

- Unshielded leads.

- Straight coaxial leads.
- 1:1 probes.
- × 10 attenuator probes.

Select the proper probe according to the amplitude and frequency of the test signal being measured. Loading effects to the test signal must also be considered.

Signal connections and loading. In general, × 10 attenuator probes offer the most convenient means of connecting a signal to the input of the Type 453. A × 10 attenuator probe offers a higher input impedance and allows the circuit under test to perform more closely to actual operating conditions. However, the × 10 attenuator probe also attenuates the input signal 10 times. The probe is shielded to prevent pickup of electrostatic interference. Low-frequency response with AC-input coupling is extended to about 0.16 Hz (30 percent down).

In some cases, the signal can be connected to the Type 453 with short unshielded leads. This is particularly true with high-level, low-frequency signals. When such leads are used, be sure to establish a common ground between the Type 453 and the equipment under test. Attempt to position the leads away from any source of interference to avoid errors in the display. If interference is excessive with unshielded leads, use a coaxial cable probe.

In high-frequency applications requiring maximum overall bandwidth, use a coaxial cable terminated in its characteristic impedance at the Type 453 INPUT connector.

As nearly as possible, simulate actual operating conditions in the equipment under test. Otherwise the equipment under test may not produce a normal signal. The × 10 attenuator probes mentioned previously offer the least circuit loading. Tektronix × 10 attenuator probes have an input resistance of about 10 megohms with very low shunt capacitance.

When the signal is coupled directly to the input of the Type 453, the input impedance is about 1 megohm paralleled by about 20 pf. When the signal is coupled to the input through a coaxial cable, this cable can increase the input capacitance to well over 100 pf.

Adjusting a probe. Before using a × 10 attenuator probe, you must check (and adjust if necessary) the compensation of the probe in order to prevent distortion of the applied waveform. Figure 2-1, a, shows the front panel of the Type 453 oscilloscope. Look at this figure and locate the "1 KC CAL" connector at the right side. Prior to connecting the × 10 attenuator probe to the test signal, insert the end of the probe into this connector. After adjusting the oscilloscope for about 2 or 3 cycles, you should have a perfect square wave displayed. If there is distortion of the 1 KC square wave, the variable capacitor within the × 10 attenuator probe needs adjusting. To adjust the probe, first unlock the locking sleeve by turning it counterclockwise. Then compensate the probe by rotating its body while you watch the scope display for the desired waveform. When this compensation has been completed, carefully turn the locking sleeve clockwise to lock it without disturbing the adjustment of the probe.

Exercises (215):

1. Give the two-line voltages to which the Type 453 can be connected.

2. If you have a 230-volt line source that measures 204 volts, in what position should you place the HIGH-LOW range switch on the rear panel?

3. What types of probes are used with the oscilloscope?

4. What type of probe should you use for a high-level, low-frequency signal?

5. What is the input impedance of the Type 453?

6. Briefly indicate how the × 10 attenuator probe is adjusted.

216. Cite the steps used to measure AC and DC voltage with the 453 oscilloscope.

Voltage Measurement. If you were troubleshooting a circuit with an oscilloscope, the AC signal displayed would be in the form of a sine wave. The amplitude of this sine wave would not be the same as that measured with a multimeter. On the oscilloscope the AC signal would be represented as a peak-to-peak signal, whereas the voltage represented on the multimeter is an RMS voltage reading. Because the technical order with which you are troubleshooting may give either peak-to-peak or RMS values, you must be able to proficiently read a peak-to-peak value on the oscilloscope and convert this reading to an RMS value.

Peak to peak. To make a peak-to-peak voltage measurement, use the following procedure:

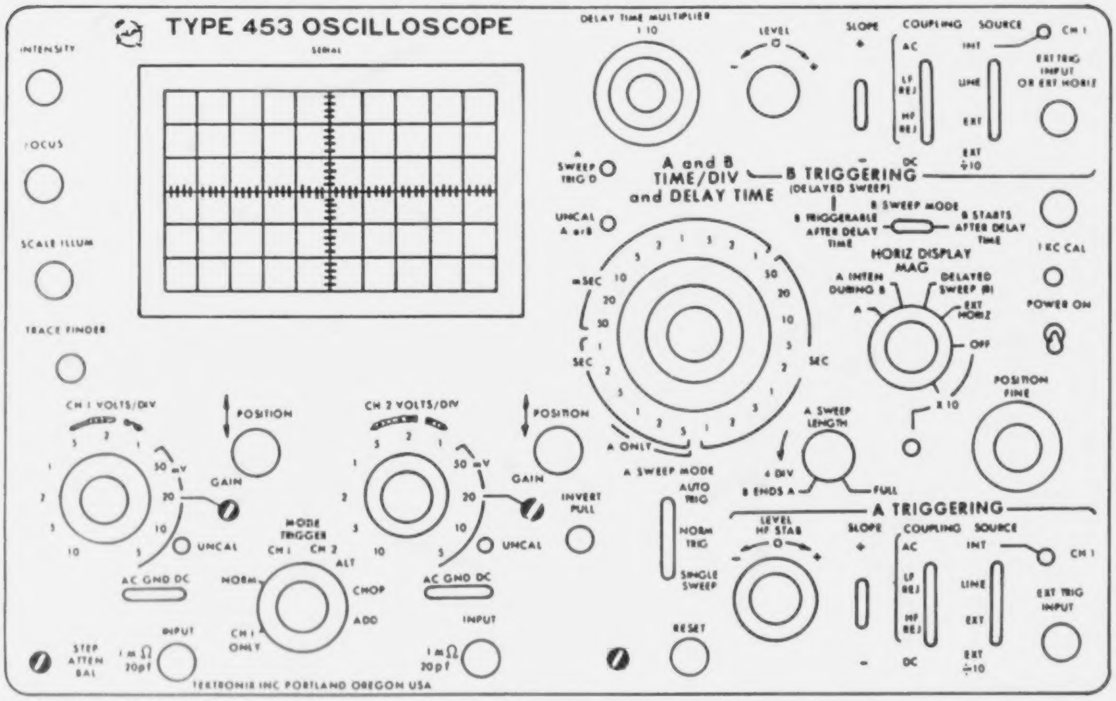
(1) Connect the signal to either INPUT connector.

(2) Set the MODE switch to display the channel used.

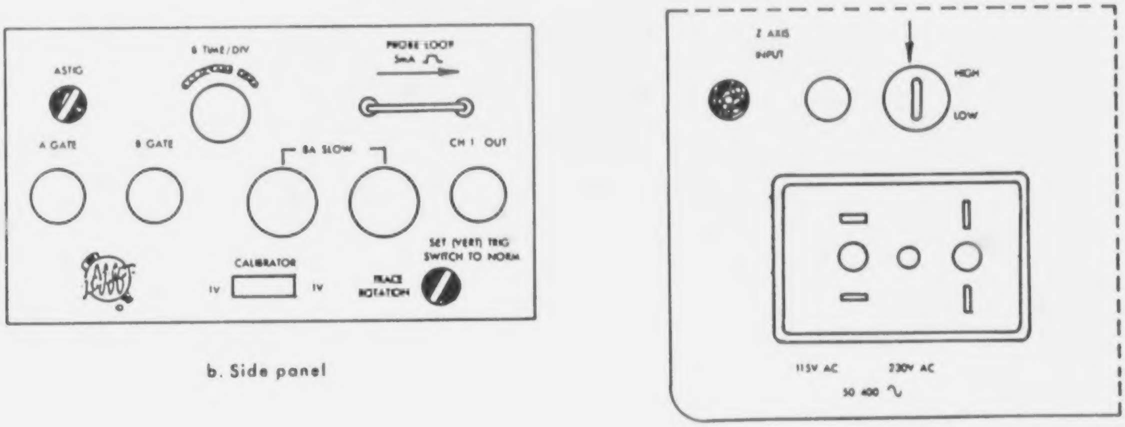
(3) Set the VOLTS/DIV switch to display about 5 divisions of the waveform.

4) Set the AC G(ND DC switch to AC. (NOTE: For low-frequency signals below about 16 Hz, use the DC position.)

(5) Set the A TRIGGERING controls to obtain a stable display. Set the TIME/DIV switch to a position that displays several cycles of the waveform.


TYPE 453 OSCILLOSCOPE
SERIAL
INTENSITY
FOCUS
SCALE ILLUM
TRACE FINDER
CH 1 VOLTS/DIV
POSITION
GAIN
UNCAL
AC GND DC
STEP ATTEN BAL
1 mΩ 20pf
INPUT
MODE TRIGGER
CH 1
CH 2
ALT
NORM
CHOP
ADD
CH 1 ONLY
CH 2 VOLTS/DIV
INVERT PULL
TEKTRONIX INC PORTLAND OREGON USA
DELAY TIME MULTIPLIER
1 10
LEVEL
SLOPE
COUPLING
SOURCE
AC
LF REJ
HF REJ
DC
INT
LINE
EXT
EXT ÷10
CH 1
EXT TRIG INPUT OR EXT HORIZ
A SWEEP TRIG'D
UNCAL A or B
A and B TIME/DIV and DELAY TIME
B TRIGGERING (DELAYED SWEEP)
B SWEEP MODE
B TRIGGERABLE AFTER DELAY TIME
B STARTS AFTER DELAY TIME
1 KC CAL
POWER ON
HORIZ DISPLAY MAG
A INTEN DURING B
DELAYED SWEEP (B)
A
EXT HORIZ
OFF
X 10
mSEC
SEC
A ONLY
A SWEEP MODE
AUTO TRIG
NORM TRIG
SINGLE SWEEP
RESET
A SWEEP LENGTH
4 DIV
B ENDS A
FULL
POSITION FINE
A TRIGGERING
LEVEL HF STAB
EXT TRIG INPUT

a. Front panel


ASTIG
B TIME/DIV
PROBE LOOP 5mA
A GATE
B GATE
BA SLOW
CH 1 OUT
CALIBRATOR
1V
1V
SET (VERT) TRIG SWITCH TO NORM
TRACE ROTATION
Z AXIS INPUT
HIGH
LOW
115V AC
230V AC
50 400 ∿

b. Side panel

c. Rear panel

C1 82-2131
0-17a

Figure 2-1. Type 453 oscilloscope.

(6) Turn the vertical POSITION control so that the lower portion of the waveform coincides with one of the graticule lines below the centerline and the top of the waveform is on the viewing area. With the horizontal POSITION control, move the display so that one of the upper peaks lies near the vertical centerline.

(7) Measure the divisions peak-to-peak vertical deflection. Make sure the VARIABLE VOLTS/DIV control is in the CAL position. (NOTE: This technique may be used also to make measurements between two points on the waveform rather than peak to peak.)

(8) Multiply the distance measured in step 7 by the VOLTS/DIV switch setting. Also include the attenuation factor of the probe, if any. EXAMPLE: Assume a peak-to-peak vertical deflection of 4.6 divisions using a × 10 attenuator probe and a VOLTS/DIV switch setting of .5. Use the formula:

$$\text{VOLTS peak-to-peak} = \text{vertical deflection (divisions)} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substitute the given values:

$$\text{Volts peak-to-peak} = 4.6 \times 0.5 \times 10$$

The peak-to-peak voltage would be 23 volts.

RMS. Prior to converting this peak-to-peak voltage of 23 volts, first convert the peak-to-peak voltage to peak voltage. Use the formula:

$$\text{Peak} - \text{to} - \text{peak} = 2\ \text{peak}$$

or

$$\text{Peak} = \frac{\text{peak} - \text{to} - \text{peak}}{2}$$

Substitute given values:

$$\text{Peak} = \frac{23}{2} = 11.5\ \text{volts}$$

RMS voltage is the same as effective voltage. Use the formula:

$$\text{Effective voltage (RMS)} = .707 \times \text{peak}.$$

Substitute the given values:

$$\text{Effective voltage} = .707 \times 11.5$$

$$\text{Effective voltage} = 8.13\ \text{volts}$$

DC Measurement. To measure the DC level at a given point on a waveform, use the following procedure:

(1) Connect the signal to either INPUT connector.

(2) Set the MODE switch to display the channel used.

(3) Set the VOLTS/DIV switch to display about 5 divisions of the waveform.

(4) Set the AC GND DC switch to GND.

(5) Set the A SWEEP MODE switch to AUTO TRIG.

(6) Position the trace to the bottom line of the graticule or other reference line. If the voltage is negative with respect to ground, position the trace to the top line of the graticule. *Do not* move the vertical POSITION control after this reference line has been established. (NOTE: To measure a voltage level with respect to another voltage rather than ground, make the following changes in step 6: Set the AC GND DC switch to DC. Apply the reference voltage to the INPUT connector and position the trace to the reference line.)

(7) Set the AC GND DC switch to DC. The ground reference line can be checked at any time by switching to the GND position.

(8) Set the A TRIGGERING controls to obtain a stable display. Set the TIME/DIV switch to a setting that will display the desired waveform.

(9) Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured.

(10) Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line, negative (INVERT switch pushed in if using Channel 2).

(11) Multiply the distance measured in step 9 by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if any.

As an example, assume that the vertical distance measured is 4.6 divisions and the waveform is above the reference line, using a × 10 attenuator probe and a VOLTS/DIV setting of 2.

Use the formula:

$$\text{Instantaneous voltage} = \text{Vertical distance (division)} \times \text{polarity} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substitute the given values:

$$\text{Instantaneous voltage} = 4.6 \times +1 \times 2 \times 10$$

The instantaneous voltage would be +92 volts.

Exercises (216):

1. How does the position of the AC GND DC switch depend on the frequency of the input signal?

2. Why must the VARIABLE VOLTS/DIV control be in the CAL position when measuring a peak-to-peak signal?

3. What is the peak-to-peak and RMS value of a voltage whose vertical deflection on the oscilloscope is 5 divisions and the VOLTS/DIV switch is 2?

4. What is the peak-to-peak and RMS value of a voltage whose vertical deflection on the oscilloscope is 4 when a × 10 attenuator probe is used and the VOLTS/DIV switch setting is 5?

5. How many divisions should be used when measuring DC voltages using the 453 oscilloscope?

6. How is a DC voltage referenced to another DC voltage?

7. How is polarity effected by using Channel 2?

8. What would be the value of the voltage given in the example in the text if the number of divisions was 4.1 and a 1:1 probe was used?

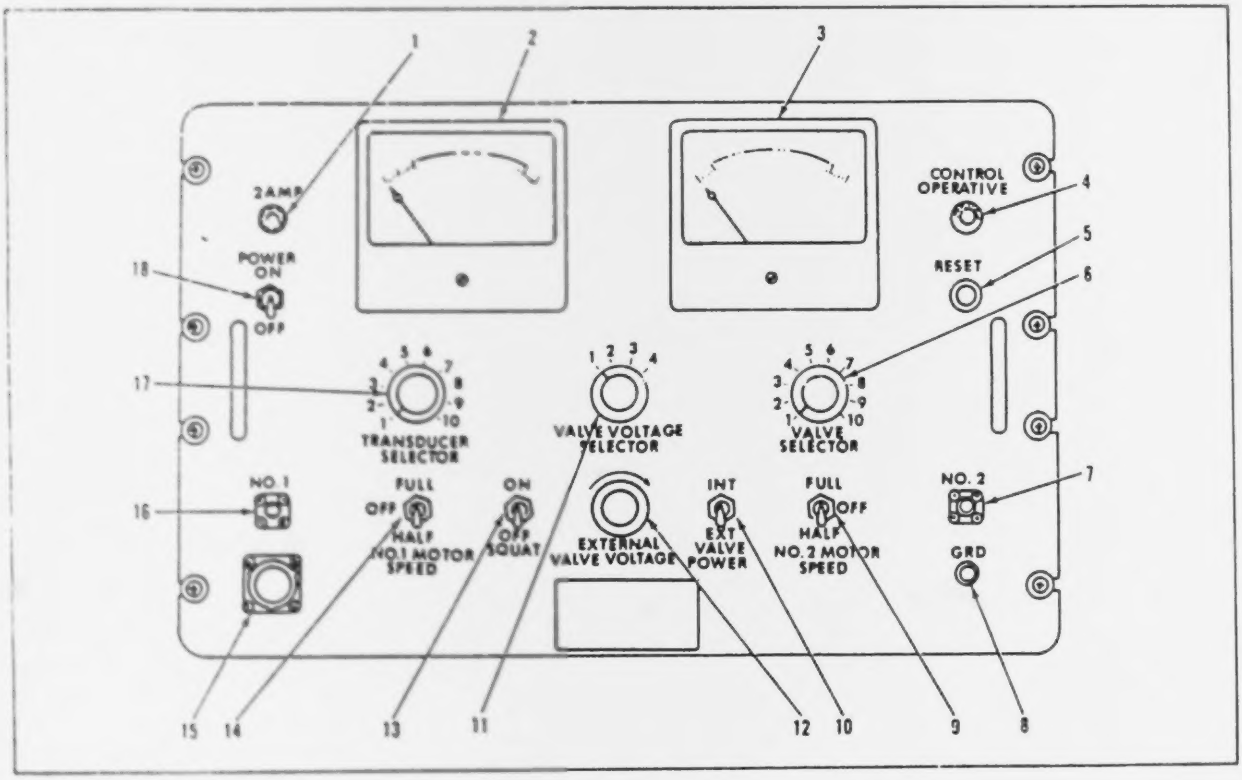
217. State procedures to follow when using the anti-skid field tester.

Anti-Skid Tester. The anti-skid field tester, PN 42-041, is used for testing various anti-skid braking systems and their components. Some aircraft have builtin testers; however, we will limit our discussion to a typical portable tester.

Description. The field tester consists of a test panel assembly, two test cable assemblies, and two drive motor assemblies contained within a small, portable, aluminum carrying case. The panel assembly is secured in the bottom half of the carrying case by eight screws and may be easily removed for use in a standard 19-inch rack. The top half of the carrying case forms a storage compartment for the test cable assemblies and the two motor assemblies.

The panel assembly consists of an ammeter, voltmeter switches, connectors, a potentiometer, an indicator lamp, and solid state circuitry. The solid state electronic components are installed in a printed circuit board assembly mounted on the underside of the panel.

Follow the index numbers, 1 through 18, on figure 2-2 as we briefly describe the function of the tester controls.


1
2
3
2AMP
CONTROL OPERATIVE
4
RESET
5
6
18
POWER ON
OFF
17
1 2 3 4 5 6 7 8 9 10
TRANSDUCER SELECTOR
1 2 3 4
VALVE VOLTAGE SELECTOR
1 2 3 4 5 6 7 8 9 10
VALVE SELECTOR
16
NO. 1
FULL
OFF
HALF
NO.1 MOTOR SPEED
ON
OFF
SQUAT
EXTERNAL VALVE VOLTAGE
INT
EXT VALVE POWER
FULL
OFF
HALF
NO. 2 MOTOR SPEED
NO. 2
7
GRD
15
14
13
11
12
10
9
8

CI 82-4508
0-10c

Figure 2-2. Anti-skid tester panel.

Index number	*Panel marking*	*Function*
1	2	AMP Protects tester from overloads.
2	- - -	Measures transducer output in microamperes.
3	- - -	Measures valve voltage (vdc).
4	CONTROL OPERATIVE	Indicates control is operative.
5	RESET	Resets CONTROL OPERATIVE lamp circuit.
6	VALVE SELECTOR	Selects valve to be tested.
7	NO. 2	Connects transducer drive motor to tester.
8	GRD	Provides external ground.
9	NO. 2 MOTOR SPEED	Controls speed of drive motor No. 2.
10	EXT INT VALVE POWER	Selects source of power to valve selected for test.
11	VALVE VOLTAGE SELECTOR	Selects valve load.
12	EXTERNAL VALVE VOLTAGE	Adjusts level of voltage to valve selected for test.
13	SQUAT	Simulates closing of squat switch.
14	NO. 1 MOTOR SPEED	Controls speed of drive motor No. 1.
15	- - -	Connects tester to anti-skid system and to aircraft power supply.
16	NO. 1	Connects transducer drive motor to tester.
17	TRANSDUCER SELECTOR	Selects transducer test mode.
18	POWER	Applies electrical power to tester.

Operation. To test the aircraft anti-skid system with the tester, you first remove the hubcaps from the wheels. Take the test cable from the field tester and connect one end of it to the connector, index number 15, on the tester. Hook up the other end of the test cable to the anti-skid control box on the aircraft. Take the two drive motors from the tester and connect one to tester connector marked No. 1, index No. 16. Connect the other motor to connector No. 2, index No. 7, on figure 2-2.

Using the aircraft instructions, turn on the aircraft power that is required to energize the anti-skid system. Now turn on the tester power switch, index No. 18. Wait about 15 minutes to allow the tester and anti-skid system to warm up before you start the tests.

Make sure you refer to the tester panel to set the controls and switches as required. Use the drive motors to rotate the transducer drive couplings. This will provide the necessary transducer signals to the anti-skid system components. Any components found to be defective must be replaced.

Exercises (217):

1. Refer to figure 2-2. What is the function of the switch in index No. 13?

2. What should you do to energize the anti-skid system?

3. What should you use to set up the tester controls?

218. State procedures to follow when using clamp-on ammeters.

Clamp-on ammeter. The AN/USM-33 multimeter is built so that it may be used as a clamp-on ammeter. It is this function of the meter that we will discuss here. The meter can measure AC current up to 600 amperes between 50 and 1,000 Hertz. The current measurement can be made in a powerline without disconnecting the line to insert the meter. A trigger-operated jaw encircles the line and measures the current in the line directly.

Theory. The laminated steel jaws or tongs act like the core in a transformer. The wire, whose current is measured, can be compared to the primary of the transformer. The magnetic field, set up by the current flowing in the wire, induces a voltage into the transformer coil. This induced AC voltage is then rectified by crystal diodes into a DC current. This DC current is measured by the meter and its associated limiting and dividing resistors. This current is read out directly on the meter face as an AC current. The strength of the magnetic field around the wire is proportional to the amount of current flow in the wire. The meter will indicate directly the quantity of current flow in the wire.

Operation. Using the clamp-on ammeter is very easy. Just hold the meter in one hand and squeeze the trigger. This opens the jaws wide enough to fit a one-inch diameter wire. Release the trigger and take the measurement. Make sure you do not touch the jaws of the meter. Hold the meter by the handgrip.

One switch on the meter is used to select the function and range. The four current ranges are marked amperes 0–15, 0–60, 0–150, and 0–600. Before you take a measurement, turn the switch to the highest range—0–600 amperes. If the current reading is below 150 amperes, remove the meter from the wire and turn the selector switch to the 0–150 ampere range. Continue this process until you have an accurate reading.

The meter has a zero adjustment on it so you can obtain accurate readings. You use an insulated screwdriver to zero the meter. The meter must be in the HORIZONTAL position to zero adjust it. Do this adjustment before you take your current measurements.

Exercises (218):

1. How much AC current can the AN/USM–33 meter measure?

2. How should you hold the meter when taking current measurements?

3. Explain two ways of getting accurate readings.

219. State the purposes of certain controls and components for the PSM–6 multimeter and state appropriate procedures and precautions for given situations.

AN/PSM–6 Multimeter. This multimeter combines the functions of a DC voltmeter, an AC voltmeter, a DC milliammeter, and an ohmmeter. When measuring a DC voltage, the operator can select a sensitivity of either 1000 ohms per volt or 20,000 ohms per volt. However, only one sensitivity is provided for the AC-voltage scales (1000 ohms per volt). Figure 2-3 shows the front panel of one of the AN/PSM–6 series multimeters.

The aluminum case comes with a cover fastened to it with four positive latches. The handle used for carrying can be locked snugly against the case for storage. It can also be locked into poistion for use as an easel to hold the instrument at a 30° angle for bench use.

Two pin jacks (one red and one black) serve for all functions and all ranges of the meter. The OHMS ADJ control is used to compensate for variations in battery voltage and internal resistance when making resistance measurements.

Function selector positions. The function selector has seven positions marked: 100μ A SPECIAL; DC MA; OHMS; DCV, 20KΩ/V; DCV, 1KΩ/V; ACVIKΩ/V; and OUTPUT.

Range selector positions. Range selector positions. The range selector also has seven positions marked: .5, 2.5 or ΩX1, 10 or ΩX10, 50, or ΩX100, 250 or ΩX1000, 500 or ΩX10,000, and 1000. The first number on each of the above positions identifies applicable voltage ranges.

Operational procedures of the PSM–6. Refer to figure 2-3 as you read the following multimeter set-up procedures:

a. Insert the red and black test leads into the proper jacks below the function and range selectors.

b. Move the function selector to the 100μ A SPECIAL position.

(1) With the function selector in this position, the range selector is not in the circuit.

(2) With the instrument so set, it is a 0–100 microampere instrument used to measure the current in series with the test leads.

(3) Observe every precaution when using this function, since only the meter is in the circuit and there is no protection from other components.

c. Move the function selector to the DC MA position and turn the range selector to the 1000 position.

(1) Always use the highest range for the first measurement of an unknown current.

(2) To measure current, always connect the tester in series with the circuit in order to get a correct reading.

d. Read the indication and turn the range selector to a position that will provide approximately a half-scale indication. An external shunt carried in the cover compartment can be used to extend the range of the meter to 10 amperes.

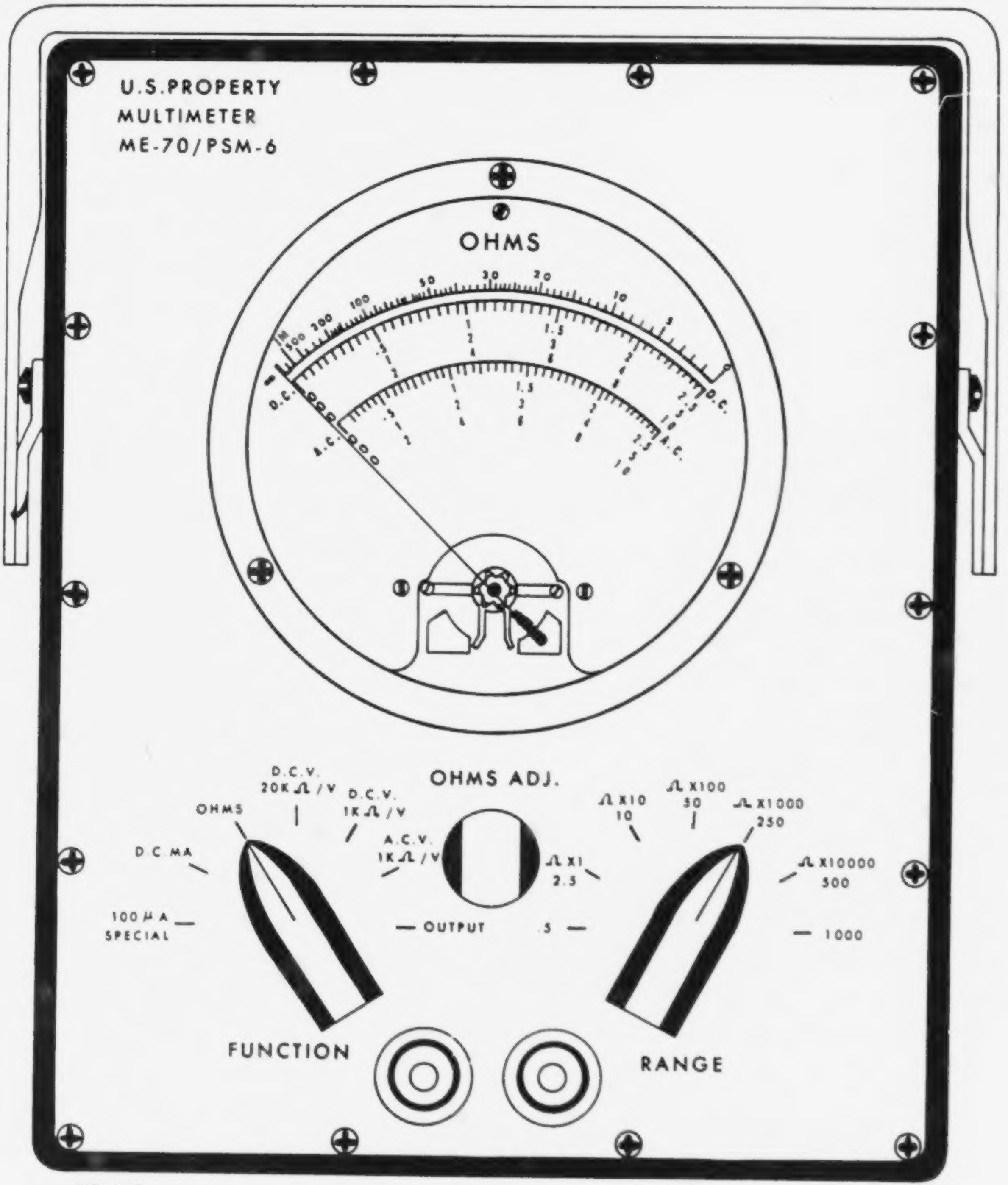
e. Turn the function selector to the DCV 20KΩ/V position. In this position the meter has a sensitivity of 20,000 ohms per volt and is set up to measure voltage in parallel with the test leads. Set the range selector at a position high enough to handle the maximum voltage in the circuit being tested.

f. Move the function switch to the DCV 1KΩ/V position and set the range selector at a position high enough to handle the maximum voltage in the circuit circuit being tested. (If in doubt as to the exact voltage, use the highest available range.) So set, the instrument is functioning as a DC voltmeter with a sensitivity of 1000 ohms per volt. Use this function of the multimeter when it is necessary to load the circuit being tested. (The high-voltage accessory probe cannot be used when the function selector is in this position.) Connect the multimeter leads in parallel with the load in order to measure voltage.

g. Set the function selector at the ACV 1KΩ/V position and move the range selector to a position high enough to measure the voltage of the circuit being tested. So set, the meter is functioning as an AC voltmeter and can be used to measure AC voltages up to 1000 volts. The rectifier in this circuit is designed to give accurate response of frequencies of 1000 Hz or less. Measurements at higher frequencies will result in inaccurate indications. (The high-voltage accessory probe cannot be used when the function selector is in this position.).

h. Set the function selector at the OUTPUT position and turn the range selector to any position marked 250 or less. This puts a one-microfarad capacitor in series with one of the test leads. This arrangement allows you to measure just the AC component of a circuit that contains both AC and DC.

(1) The procedure for taking these measurements is the


U.S.PROPERTY
MULTIMETER
ME-70/PSM-6
OHMS
∞
M
500
200
100
50
30
20
10
5
0
D.C.
A.C.
.5
1
1.5
2
2.5
4
6
8
10
OHMS ADJ.
D.C.V. 20KΩ/V
D.C.V. 1KΩ/V
A.C.V. 1KΩ/V
OHMS
D.C.MA
100μA SPECIAL
OUTPUT
ΩX1 2.5
.5
ΩX10 10
ΩX100 50
ΩX1000 250
ΩX10000 500
1000
FUNCTION
RANGE

C181-1163
0-4a

Figure 2-3. PSM-6 multimeter.

same as that used for getting an AC measurement.

(2) The maximum voltage that can be measured is 200 volts.

(3) The indications will not be accurate, because the impedance of the capacitor varies with the frequency of the voltage being measured.

i. With the function switch set on OHMS, the meter serves as an ohmmeter. In the ohmmeter, the same basic galvanometer unit is used in conjunction with an internal source of low voltage (a small battery) and one or more resistors. The ohmmeter operates on the principle that current flow decreases as resistance increases. It is adjusted by placing the external leads together and adjusting the variable resistor until the meter reads zero ohms. With the two external leads connected together, there is no resistance in the external circuit; hence the zero reading is obtained. Now separate the leads and place them at two different points of a circuit. So set, current will flow from the small battery in the ohmmeter through the resistance, then through the meter, and back to the battery. The more resistance between the contact points, the less the current flow will be. The smaller the current flow through the meter, the less the needle moves. If there is no current flow, the needle remains on the left end of the scale. At that point the scale reads infinity (RESISTANCE WITHOUT END). If there is high-current flow, the needle moves all the way to the right, where the scale reads zero resistance. The variable resistor (OHMS ADJ) in the circuit is used to compensate for the variations in the battery voltage. As the battery ages, it grows weaker. When it is no longer possible to return the pointer to zero with the adjustable resistor, replace the battery.

Most ohmmeters now in use include multiplier circuits. These expand the range of values to provide more accurate resistance measurements over a wide range. When a change from one resistance range to another is made, the meter has to be zeroed again. (CAUTION: All sources of voltage must be disconnected from the circuit undergoing resistance measurements before the connections to the ohmmeter are completed. If the ohmmeter is accidentally connected into a "hot circuit," the meter will probably burn out.)

Care and safety. When you use this test equipment, care for it. Multimeter instruments are expensive; handle them as though you had paid for them out of your own pocket. Even though they are mounted in well-designed cases that protect them, rough handling can result in permanent damage to the sensitive meter movement. Finally, when you are making electrical measurements, be sure to start with a scale or range that will insure against overloading the meter.

Corrosion from a discharged battery can result in irreparable damage to the components of the unit. Therefore, a fresh battery must be kept in the ohmmeter section. To check the battery, turn the function selector to the OHMS position and zero the meter on each of the resistance ranges. When it will not zero on one or more of the ranges, replace the battery.

While working on the aircraft or its equipment, always protect yourself and the equipment. Be careful with the test probes, because an arc in the area containing explosive fumes could be disastrous. A high-voltage area is also dangerous. Practice safety at all times. Remember, high voltages can be lethal. Therefore, when you are measuring voltages greater than 100 volts, observe the following precautions:

a. Connect a grounded lead to one of the panel screws of the multimeter to ground the instrument case.

b. If possible, connect and disconnect the test leads with the power supply off.

c. Also, if possible, take the meter reading without touching any part of the multimeter.

Exercises (219):

1. Why could we say that the PSM–6 is a very versatile unit?

2. Other than carrying, what other purpose can the PSM–6 carrying handle be used for?

3. What is the ohms adjust control used for?

4. a. How should the PSM–6 be set up if you were checking to see if there were 80 microamps in a circuit?

   b. How are the meter leads placed, i.e, in respect to the component?

   c. Where would you position the range selector? Explain.

5. a. If you were to make a very sensitive but accurate 10- or 12-volt DC check, where would you set the selector switch?

   b. Explain how you would use the range switch.

c. If 10 or 12 volts are supposed to be applied to a resistor, explain how the leads are positioned to make this check.

6. While using an ohmmeter to take resistance readings, what preliminary precaution should be taken?

7. When you are making electrical measurements, what precaution should you take to avoid overloading the circuit?

8. What precautions must be taken when the batteries in the meter are checked?

9. As you go through the procedure called for in exercise 8 above, what indication might you get that the batteries should be replaced?

10. What precautions should be observed when you are measuring voltages greater than 100 volts?

220. State the purpose of frequency meters and how to use them.

Frequency Meters. In some AC systems it is necessary to check and adjust, if necessary, the frequency of the voltage source. Several types of frequency meters are suitable for making this type of check. Two of these are the dynamometer-type frequency meter, which uses the electrodynamometer principle, and the vibrating reed-type meter, which is an electromechanical type of instrument.

Dynamometer type. The dynamometer-type frequency meter uses a dial and pointer. If the frequency is actually 60 cycles or Hertz, the pointer points to 60. If it should be 120 cycles or Hertz and is only 110, the pointer will point to 110.

The A-1 dynamometer frequency meter is commonly used by Air Force electricians. This meter can be calibrated to directly read the exact frequency. In this meter, the current does not increase at a uniform rate, but increases more rapidly as resonance is approached. This meter can be used for only a small frequency range.

Vibrating reed type. The vibrating reed-type meter contains an electronmagnet mounted near a metal plate. When the electromagnet is energized with AC, vibrations are set up. These vibrations are transmitted to a metal plate, part of which consists of a set of carefully balanced metal reeds. Each reed vibrates excessively at one particular frequency. If more than one reed is vibrating, the one vibrating the most indicates the nearest correct frequency. You take readings with both types in the same manner as you would take voltage readings with a voltmeter.

Care and storage. Frequency meters, like the ones previously discussed, are enclosed in a metal case. This, however, does not always keep them from being damaged. Do not allow the meter leads to hang out when they are not in use. Take care to see that they won't be crushed or pinched when the cover is put in place.

When the meter is not being used, store it in the shop where it will not be subjected to extreme or varying temperatures, dampness, or jarred around. Taking care of test equipment will lengthen its life and it will give you good trouble-free service.

Exercises (220):

1. What is the purpose of a frequency meter?

2. Compare how reading the dynamometer differs from reading the reed-type frequency meter.

3. To read frequency, how are the meters attached to the circuit?

4. Describe storing precautions that should be observed when storing meters and test equipment.

221. Cite the use of the insulation tester.

AN/PSM-2A Insulation Tester. the AN/PSM-2A insulation Tester is commonly known as a "megger." This megger is a portable insulation resistance test set used for measuring high values of resistance, such as the resistance of the conductor to insulation breakdown. It consists of a high-range ohmmeter and a hand-operated DC generator mounted in the same case. The resistance range of the megger usually extends from 0 to 1000 megohms or more, and the ohmmeter is of special design. The generator may deliver a potential of 500, 1000, or 2000 volts at the test terminals, but in military applications, a 500-volt DC generator is generally used.

This meter is called a true or differential ohmmeter because the position of the pointer is determined by the difference between two forces. One force, the current coil, tends to move the pointer toward 0. The other force, the potential coil, tends to move it toward infinity. The system comes to rest at a point where the two forces are balanced. The position depends on the value of the unknown resistance. This position does not depend on the voltage generated within the equipment, as in an ordinary ohmmeter. This is because the generator supplies current to both coils so that any change in its output voltage affects the coils in the same proportion.

Before connecting the megger to the equipment to be tested, all power should be disconnected. Because of the small amount of torque and the lack of balance springs in the movement, the megger should be kept in an *upright* position and placed away from strong external magnetic fields, so that the reading is not affected. The test leads are then connected to the megger and the megger tested for leakage. With the test lead open, the meter should read infinity; when the test leads are short-circuited, the meter should read zero. Then, the test leads are connected to the device whose insulation resistance is to be checked. The handcrank is then rotated until the clutch slips and the meter reading becomes steady. A reading is taken which is compared with the proper value of insulation resistance. It is important that the insulation resistance be measured at the same temperature every time an insulation test is made because the resistance of insulation drops sharply at high temperatures. For example, the insulation resistance between the stator winding of a certain slow-speed generator and the frame is 100 megohms at 85° F. The insulation resistance of the same equipment falls to only 10 megohms at 140° F.

Exercises (221):

1. Tell what the megger is used for and cite an example.

2. Why should the megger be kept away from strong external magnetic fields?

222. Cite the use of the thermoswitch tester.

Thermoswitch Tester. The X-1A thermal switch tester as shown in figure 2-4 is used for testing and when making adjustments on types E-2 and E-4 overheat detectors, as well as other types of thermal switches used in aircraft overheat systems. The X-1A tester will test both the "normally open" and the "normally closed" switches with equal ease and accuracy. It has the capability of checking switches with a range of 200° to 1000° F. (93° to 537.7° C.).

The tester (see fig. 2-4) is designed to operate on 115 VAC, 60 Hz. It is designed to heat the thermal switch under test to the temperature at which it should operate. You can vary and control the temperature to accommodate all types of switches within its range.

The POWER ON-OFF switch is a four-way range switch.

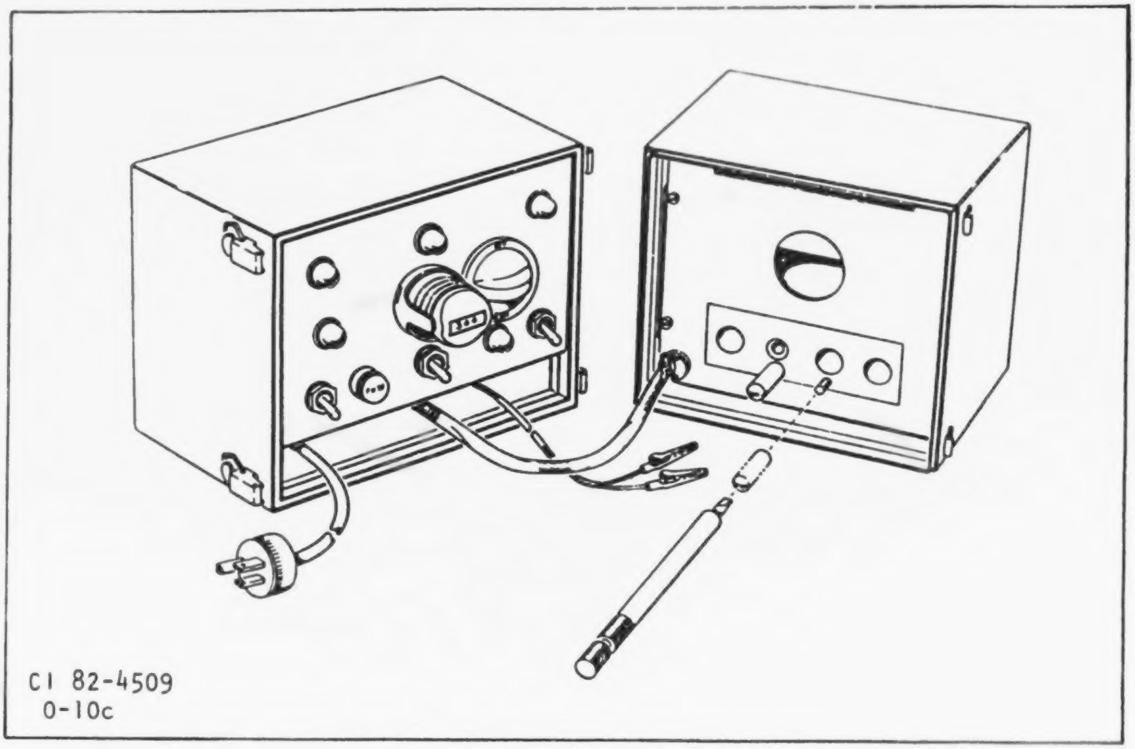


Figure 2-4. X-1A thermal switch tester.

The positions are off, low, medium, and high. The high position is used to start the test. As soon as the temperature of the block is within 50 degrees of the testing temperature, you switch to medium or low position for the rest of the test. Use the medium position for switches between 700 to 1000 degrees. You should use the low position for switches below 700 degrees.

Exercise care when working around the heat block, thermal switches, and associated parts. They can become extremely hot. Observe safety precautions at all times to avoid dangerous burns. Also, if the tester is to be left unattended, avoid leaving the heat switch in the HIGH position.

Exercises (222):

1. What does the POWER ON-OFF switch do?

2. What types of over-heat detectors can the X-1A test?

3. When should you use the HIGH position on the X-1A?

2-2. DC Test Equipment

In order for the electrician to keep the power system at its highest peak of efficiency, he must have special test equipment. The requirement for this special test equipment has been brought about by the complexity of today's systems.

As the name implies, the equipment to be tested operates in a DC system. To control system operation and in order to determine discrepancies, test equipment has been built to simulate aircraft operation. This test equipment is the subject in this section.

223. Cite operational fundamentals of the two testers used in testing DC generator system components.

DC Generator Test Stand. You have no doubt realized the importance of the generator test stand. Figure 2-5 is a picture of a typical A-2 test stand. Don't be alarmed if it isn't the same as the one that you have in your shop. There are different versions still in service. However, they all perform the same two basic functions: (1) they turn the generator at various speeds and (2) they provide a means of applying a load to the generator under test.

What are some of the capabilities of the generator test stand? The A-2 test stand simulates the operational service conditions for testing 30-volt DC generators with ratings up to 600 amperes. It is usually referred to as a varidrive since it provides a means of regulating generator speed. It also provides a means of applying loads to the generator under test.

On top of the test stand there is a resistive load bank. The switches (item C, fig. 2-5), located on the front panel, control the resistive load bank to provide a load for the generator under test. When a switch is placed in the ON position, it connects a bank of resistors in parallel with those already in the circuit.

A variable resistor (item A, fig. 2-5) is provided for a variable control of generator current output from 0 to 25 amperes. This resistor adds a limited amount of resistance in parallel with the bank resistors.

To control the generator output voltage, a variable 0- to 10-ampere generator field control (item B, fig. 2-5) is provided. This rheostat allows more resistance to be placed in series with the generator field, thereby controlling the generator output voltage.

There are various types of meters on the face of the panel. These meters indicate the various aspects of generator performance such as voltage, current, and speed of the generator. You should become completely familiar with each meter and all other controls before attempting to operate the test stand.

The basic generator test stand is unable to check all of the generator system components. But, with a little work on your part, you can greatly increase the capabilities of the test stand. All you have to do is to modify the stand to incorporate the wiring of the basic generator system.

Modification. The enclosed portion (D) of figure 2-5 is a modification that was performed by the local electric shop. You will probably recognize the components as being DC generator system components.

Normally you aren't allowed to modify anything without the proper authority. Furthermore, modifications should be limited to the external mounting of components which would not affect the basic test stand. In this way, you can also change the modifications to meet new needs.

Modifications should be performed only if it increases the versatility of the test stand. Since the test stand provides a means of turning the generator and applying loads, why not incorporate the other generator system components? The modified test stand would then enable you to test all generator system components. This would include testing and calibrating the voltage regulator, field control relay, RCR, overvoltage relay, and of course, the generator. Since the generator can be driven at various speeds and various loads applied, a thorough check of component operation can be made.

This modification is a mockup of the aircraft generator system. Most DC generator systems are basically the same. Therefore, one system can probably take care of all your needs. The components should be mounted in such a manner that they can be replaced easily by the component under test. All wiring and connections should be installed with the same care and precautions used in aircraft wire maintenance. A neat and systematic layout of the components produces a piece of test equipment of which you will be justly proud.

Servicing. Maintenance of the generator test stand is the responsibility of the electric shop personnel. Whenever you are placed in a position that requires you to operate the stand, you should also be aware of the maintenance requirements. The test stand TO covers the maintenance of

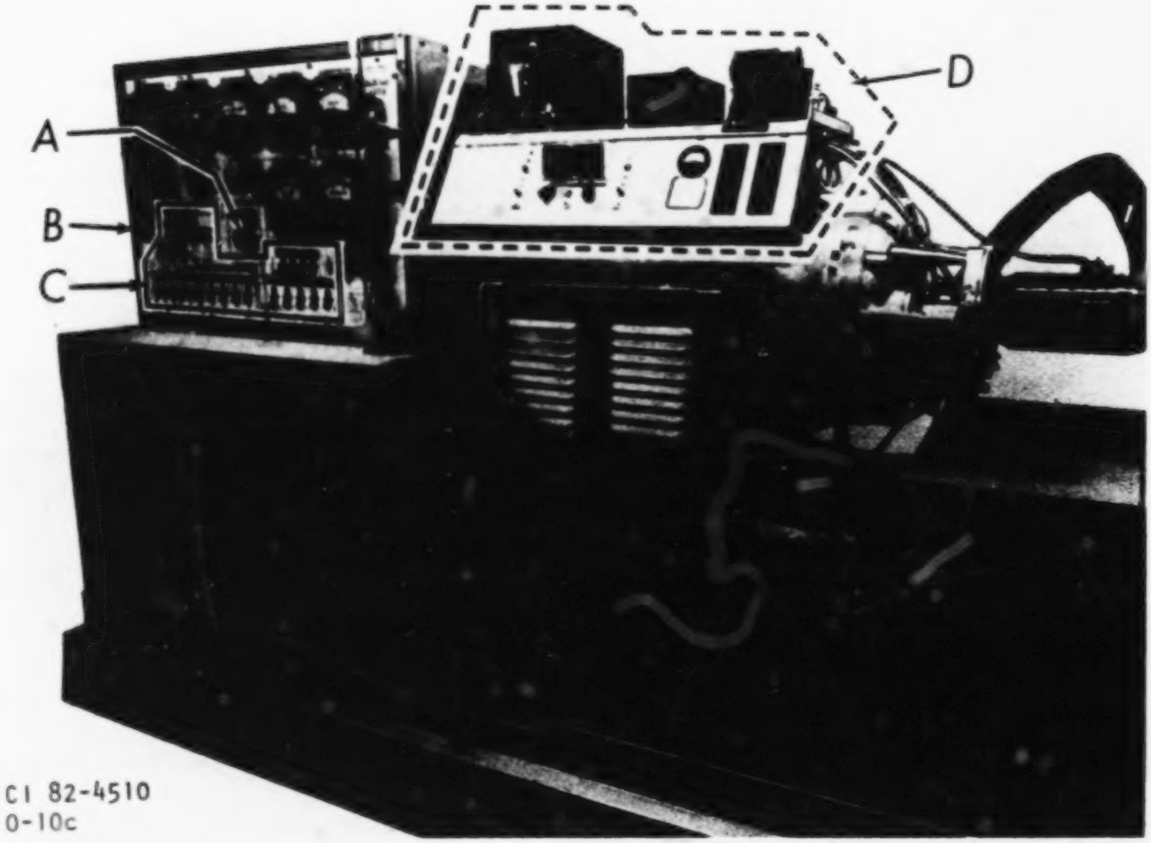


Figure 2-5. A-2 generator test stand.

the stand as well as the operating procedures. So, after you finish reading the section on operation, continue and read the maintenance requirements.

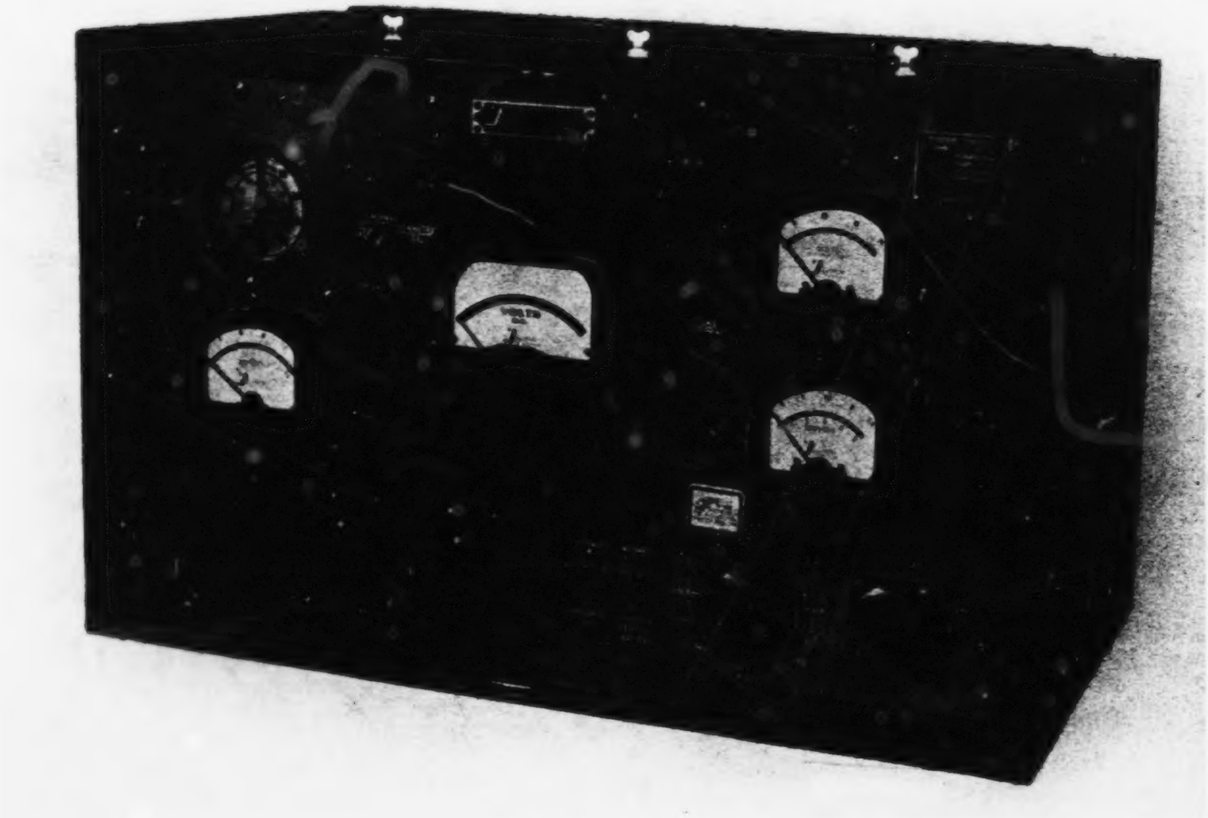
The importance of preventive maintenance of the stand cannot be overstressed. It must be properly inspected and serviced just like any other piece of mechanical equipment. It pays to properly grease and lubricate the stand at the prescribed intervals. You know—we might even consider this action as an insurance policy. It's much easier to spend a little time servicing the test stand than it is to explain to the DCM why you had a bearing failure. This is especially true if it occurred due to a lack of lubrication and happened at some crucial time. So always remember to check the applicable TO and keep the test stand properly serviced.

Safety. Become familiar with the TO that applies to your equipment. Get checked out on the operation of the test stand. Then become safety conscious and always remain so. Follow these three steps before you start working on or operating any test stand.

T-31 Tester. The model T-31 DC system tester (fig. 2-6) is designed to provide a fast and uniform method of testing and adjusting DC generator control panels. With special wire harnesses, it can be adapted to test other DC system components. This tester is powered by 115 volts AC and does not incorporate the use of a DC generator. You may conduct the bench check of a control panel without access to the internal components since all indications of proper relay functioning are visible on the tester by means of lamps and meters. A 12-position selector switch on the panel face automatically connects the proper voltmeter range, the proper indicator lamp, and correct electrical power to the various circuits in each component.

DC control panels, as previously mentioned, are getting rather scarce since most of the newer aircraft are turning toward AC power. However, there are still many uses for this tester in shop repair work. Various test harnesses can be made up so that you can use the timer or any of the other meters on the front panel. This provides you with a means of testing many other system components.

If your shop has a T-31 tester, we suggest that you get the applicable TO and read it. Here you find the step-by-step operating procedure and a wiring diagram for the tester. The diagram will be helpful when you want to adapt the tester to uses other than those for which it was designed. Maintenance on the tester is limited to the repair of electrical circuit malfunctions. These will be few and far between if the tester is operated as prescribed in the TO. Any other repair or overhaul required should be done in



CI 82-4511
0-10c

Figure 2-6. T-31 tester.

accordance with the applicable TO. If the test equipment fails to operate for any reason, check the TO for that equipment and refer to the troubleshooting chart. It could save you a lot of time and effort.

Exercises (223):

1. What two testers are used to test DC generator system components?

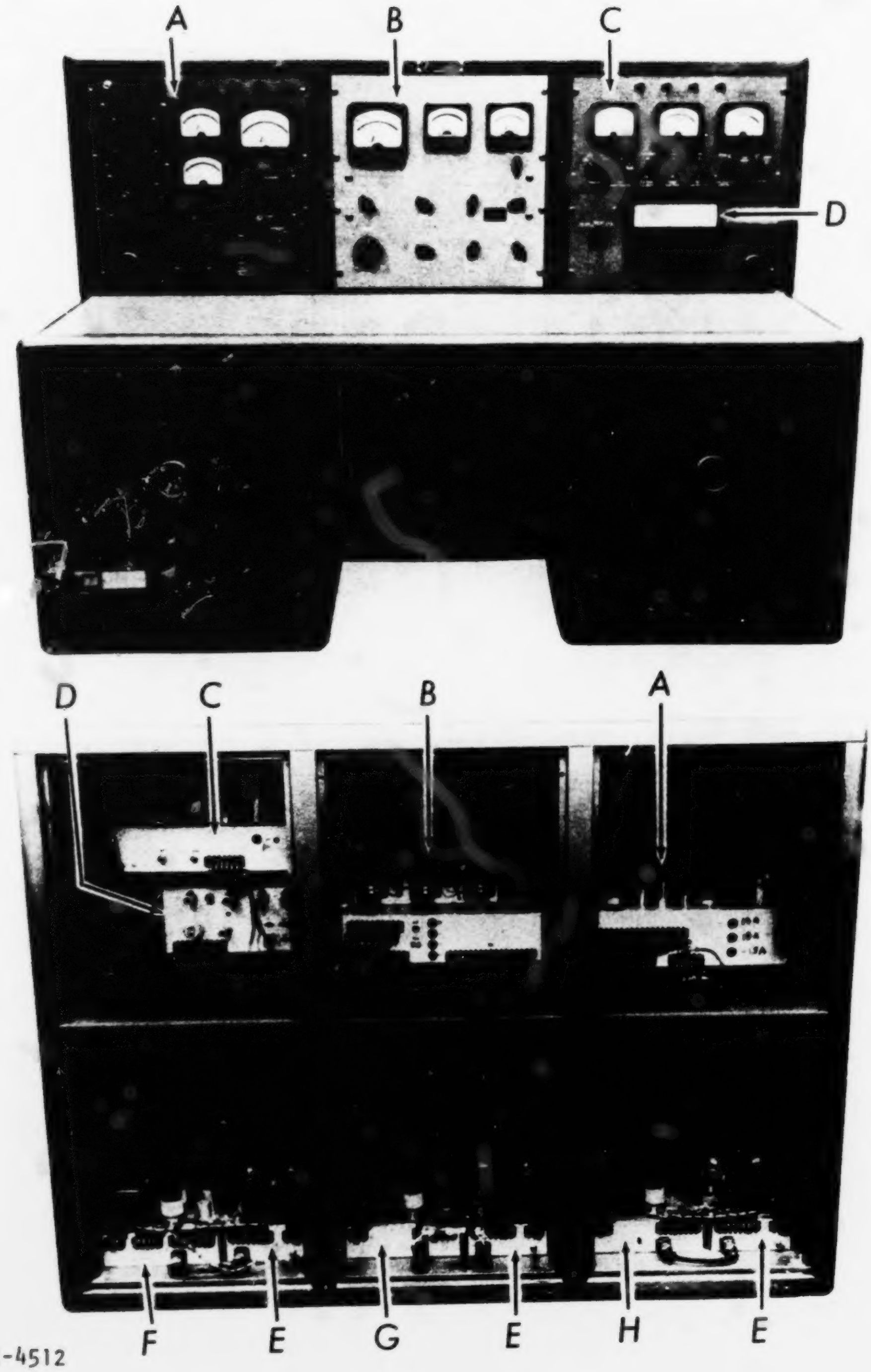
2. What component cannot be tested on the T-31 tester that can be tested on the A-2 test stand?

3. Can the A-2 test stand be made to test components other than the generator? If so, how?

4. What powers the T-31 tester?

2-3. AC Test Equipment

Formerly, DC power systems were the prime electrical system on aircraft, but today the new aircraft are AC powered. As pointed out earlier, the vast majority of the systems on an aircraft are in some ways dependent upon electrical power. The more systems dependent upon electricity, the more variable the levels of voltage will have to be. AC is a good source of power that can be easily changed in potential. Since AC is more prominent than DC now, it is logical to devote more space to the testers of AC power equipment. Another reason for more coverage is that AC power systems are more diverse in components and operation than are DC power systems. For these reasons, the rest of this chapter will cover AC power systems test equipment. The first piece of test equipment we will consider is the T-35 tester. Then we will cover the T-170, MC-2, and A-1 tester.



CI 82-4512
0-10c

Figure 2-7. T-35 tester.
A. DC-Power Metering and Control Unit
B. AC-Metering and Control Unit
C. Metering and Control Unit for Constant-Speed Drive Control
D. AC Electronic Generator
E. Power Amplifiers
F. Power Supply (A Phase)
G. Power Supply (B Phase)
H. Power Supply (C Phase)

224. Cite the functions and operational characteristics of the T-35 tester.

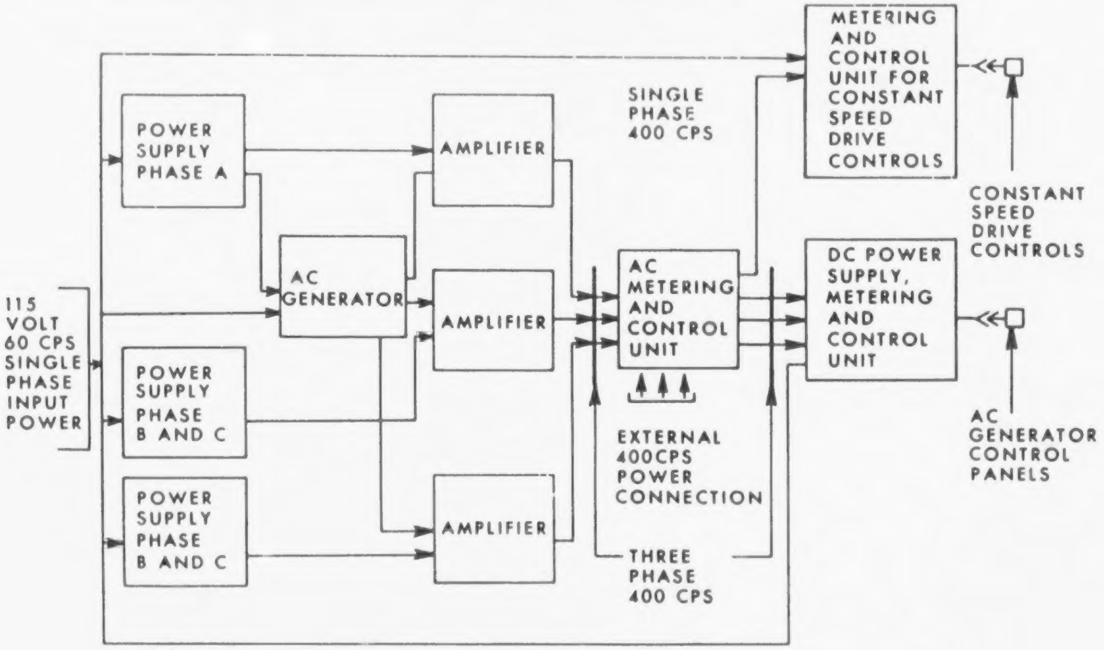
The T-35 Tester. The T-35 tester, or control panel test set, is designed specifically as a general purpose test set for all AC-control and protection panels *not* containing transistors. The voltohmmeter is used for troubleshooting, and the test set is used for operational performance. The test set tells you the status of each item in the control and protection panels. You can test the performance of your equipment with this tester by simulating various voltage or frequency conditions that may occur in flight. you are responsible for operation and maintenance of this test equipment. The following discussion is designed to acquaint you with the various circuits and components within the test stand. The T-35 tester provides a fast and uniform method of testing and adjusting certain AC power generator system components. In order to test other AC power-generating components, special test leads are necessary. The components to be tested and adjusted, which will use all the test set circuits and meters, are the AC control panels, frequency and load controllers, autoparalleling controls, and underspeed controls.

Components. The T-35 test set consists of an AC electronic generator, power amplifier, amplifier power supplies, an AC metering and control unit, a DC power supply metering and control unit, and a metering and control unit for the constant-speed drive controls (see fig. 2-7). These units are housed in a desk-type console and are interconnected to provide a complete test set for checking certain makes and models of the generator control panels and constant-speed drive controls and their components. The components that make up the test stand are mounted on shelves in the back of the tester and are easily accessible through inspection doors.

Item A in figure 2-7 is the DC power metering and control unit. Item B is the AC metering and control unit. Item C is the metering and control unit for constant-speed drive control. Item D is the AC electronic generator. Item E is the power supply and items F, G, and H are the phase A, B, and C power supplies respectively.

Operation. The T-35 tester is used for control panels rated at 115/200 volts, 400 Hz, single or three-phase. The input required for the set is 115 volts, 60 Hz, single-phase power with a maximum load of 10 amperes. The maximum output of the 400-Hz AC generator is 90 volt-amperes per phase. The three-phase voltage is adjustable from 0 to 150 volts. Single-phase voltage, manually adjustable from 0 to 300 volts, is also provided. Fixed DC power is available at 26 volts nominal. A variable DC voltage is available and is adjustable from 0 to 60 volts. The test set subassemblies are connected together with harness assemblies. The relationships of the subassemblies are shown in the block diagram of figure 2-8.

Power supply, phase A. This power supply provides the necessary plate, bias, and tube heater power to the AC generator. A transformer and a 5Y3 rectifier tube with a filter network supply a positive 280 volts DC. The highest voltage secondary of this transformer is also connected to a 6X4 rectifier tube which supplies a negative voltage through a filter network to an OB2 regulating tube. This voltage-regulating tube provides a negative 108 volts DC, which is the reference voltage for the output voltage regulator of the amplifier.


METERING AND CONTROL UNIT FOR CONSTANT SPEED DRIVE CONTROLS
SINGLE PHASE 400 CPS
POWER SUPPLY PHASE A
AMPLIFIER
CONSTANT SPEED DRIVE CONTROLS
AC GENERATOR
AC METERING AND CONTROL UNIT
DC POWER SUPPLY, METERING AND CONTROL UNIT
115 VOLT 60 CPS SINGLE PHASE INPUT POWER
AMPLIFIER
POWER SUPPLY PHASE B AND C
EXTERNAL 400CPS POWER CONNECTION
AC GENERATOR CONTROL PANELS
POWER SUPPLY PHASE B AND C
AMPLIFIER
THREE PHASE 400 CPS

CI 82-4513
0-10c

Figure 2-8. Block diagram of the T-35.

The heater power at 6.3 volts AC for the amplifier is furnished by the secondary of another transformer. The highest voltage secondary of this transformer is connected to a 5Y3 rectifier tube with the rectified output filtered. This output, 300 volts DC, provides plate voltage for the low-level stages of the amplifier. Through a voltage divider network, a negative grid bias of 50 volts DC is obtained for the output stage of the amplifier. Another transformer has its high-voltage secondary connected to two 5R4 rectifier tubes. These tubes are connected in parallel. The output of these two tubes provides 750 volts DC to the plate of the output stage of the phase A amplifier.

Power supply, phase B and C. These power supplies furnish the plate, bias, and heater power for the amplifier for the phases B and C amplifiers (see fig. 2-8). The operation of these power supplies is identical to the power supply for phase A, which we discussed previously.

Power amplifiers. The electronic amplifiers are used to amplify the low-level, three-phase voltages produced by the AC generator. These three, phases A, B, and C amplifiers, are identical in construction and operation. They increase the power to each line-to-neutral voltage; and each supplies a voltage, adjustable over a range of from 95 to 130 volts AC, delivering approximately 90 volts-amperes at 115 volts. The output voltage is independent of load variations and does not exceed ± 0.5 volt from no load to full load. Each amplifier is connected to a power supply which provides the necessary plate, bias, and tube heater voltages.

AC electronic generator. This generator is a stable electronic oscillator with a balanced three-phase output. The frequency range of from 310 to 440 Hz uses a resistor-capacitor network for frequency determination, while the frequency ranges of from 390- to-410 Hz and from 4907-to-5760 Hz use an inductor-capacitor parallel resonant circuit for their frequency determination. The single-phase output of the oscillator is connected to a single- to three-phase static converter. These three-phase voltages are fed to the three-power amplifiers, as shown in the block diagram, figure 2-8. For the high-frequency range, the single-phase output of the oscillator is connected to a two-stage cascaded amplifier. The single-phase voltage is then applied to the power amplifiers for further amplification.

AC metering and control unit. This unit controls the three-phase voltage and provides voltages of adjustable levels and correct phases. It incorporates meters for making various voltage and current measurements. The three-phase voltage from the power amplifiers is applied to a three-phase variable autotransformer. The output of this autotransformer is adjustable by the AC VOLTS control, shown in figure 2-9. Each specific switch position on this unit provides certain operating conditions. When the AC VOLTS switch is in the UNBAL 150-V position, the voltage of the phase selected by the PHASE SELECTOR switch is varied by the AC VOLTS control (autotransformer), while the voltages of the other two phases are held at 115 volts. Other positions of the AC Volts switch allow for selecting three-phase balance 150-V, three-phase balance 300-V, three-phase unbalance 300-V, single-phase 7.5-V, single-phase 20-V, single-phase 150-V, and single-phase 300-V positions.

DC power supply metering and control unit. This unit provides both fixed and adjustable DC power. It incorporates meters for making various voltage, current, and resistance measurements and a timer for determining response times. Indicator lamps are provided for indicating relay contact operation in the unit undergoing test. A fixed DC power supply provides 26 volts DC for operation of the timer clutch and the indicator lamps. The testing procedure can be performed on a typical AC protection panel after the preliminary setting of switches and controls (see fig. 2-9). Every item in the AC protection panel can be tested. For example, the generator control relay (GCR) trip circuit may be checked by placing the TEST switch (No. 7, fig 2-9) in POSITION 1 and by turning the DC power switch (No. 3, fig. 2-9) ON and rotating the DC volts control (No. 20, fig. 2-9) until the GCR trips and lamp No. 2 goes out. The trip voltage may read 18 volts or less on the DC voltmeter (No. 28, fig. 2-9). Below are other checks that can be performed on the AC protection panel.

a. Undervoltage.
b. Overvoltage relay check.
c. Overvoltage relay time-delay check.
d. Selector relay and bias circuit check.
e. Open-phase relay No. 1 check.
f. Differential protection relay check.
g. Control panel test switches check.
h. Open-phase relay No. 2 check.
i. Anticycling relay check.
j. Time-delay relay No. 1 check.
k. Auxiliary relay No. 3 check.
l. Transformer-rectifier check.

Always refer to the applicable technical order in testing AC protection panels.

The information which we have presented on the T–35 tester is intended only to acquaint you with the test capabilities and the functions of the various test set components. Also, note that the T–35 tester is somewhat limited when it comes to testing the more sophisticated transistorized AC power system components.

Troubleshooting and repair. If the tester fails to operate for any reason, a systematic procedure should be used to troubleshoot it. Naturally, the first place you would check would be the power source. From there, you would check the circuit protection devices on the tester. From there you would have to go into the tester. You will only disassemble the test to the extent necessary to repair or replace the defective part or to correct a faulty condition that has been found. Any repair or overhaul required should be done in accordance with the applicable TO. A troubleshooting chart is located in most TOs to aid you in finding the trouble.

Exercises (224):

1. What components will the T–35 tester check?

2. Is the T–35 tester a shop tester or a portable tester?

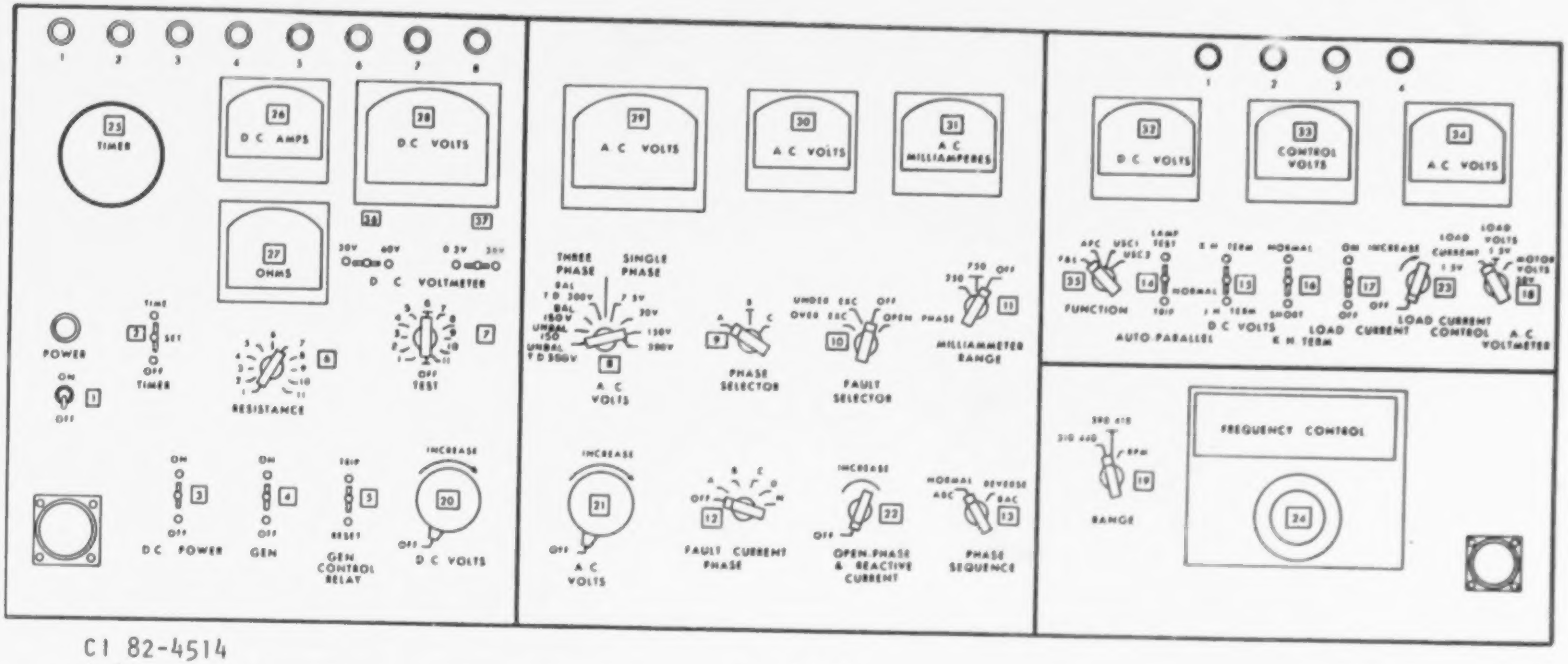

1
2
3
4
5
6
7
8
25
TIMER
26
D C AMPS
28
D C VOLTS
27
OHMS
36
37
30V
60V
0.3V
30V
D C VOLTMETER
POWER
TIME
SET
OFF
TIMER
ON
OFF
1
2
RESISTANCE
6
OFF
TEST
7
ON
OFF
3
ON
OFF
4
TRIP
RESET
5
INCREASE
20
OFF
D C POWER
GEN
GEN CONTROL RELAY
D C VOLTS
29
A C VOLTS
30
A C VOLTS
31
A C MILLIAMPERES
THREE PHASE
SINGLE PHASE
BAL
T D 300V
BAL
150V
UNBAL
150
UNBAL
T D 300V
7.5V
30V
150V
300V
8
A C VOLTS
9
PHASE SELECTOR
UNDER EXC
OFF
OVER EXC
OPEN
10
FAULT SELECTOR
750
OFF
250
PHASE
11
MILLIAMMETER RANGE
INCREASE
21
OFF
A C VOLTS
A
B
C
OFF
N
12
FAULT CURRENT PHASE
INCREASE
22
OFF
OPEN-PHASE & REACTIVE CURRENT
NORMAL
REVERSE
ABC
BAC
13
PHASE SEQUENCE
1
2
3
4
32
D C VOLTS
33
CONTROL VOLTS
34
A C VOLTS
APC
USC1
USC2
FBS
LAMP TEST
35
FUNCTION
14
NORMAL
TRIP
AUTO PARALLEL
E N TERM
J N TERM
15
D C VOLTS
NORMAL
SHORT
16
E N TERM
ON
OFF
17
LOAD CURRENT
INCREASE
OFF
23
LOAD CURRENT
1.5V
LOAD VOLTS
1.5V
MOTOR VOLTS
SET
18
LOAD CURRENT CONTROL
A C VOLTMETER
390 410
310 440
RPM
19
RANGE
FREQUENCY CONTROL
24

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Figure 2-9. T-35 control panel.

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3. What is the power requirement of the T–35 tester?

4. If a malfunction occurred in the T–35 tester, to what should you refer?

225. State operational charactertistics of the T–170 test stand.

The T–35 tester we just dicussed does a fine job of testing AC control and protection panels that are not transistorized, but in today's world of electronics, we also need a tester that has the capabilities of testing transistorized circuits. This brings us to the next test stand, the T–170.

T–170 Tester. The T–170 tester is designed to provide a fast and uniform method for testing and adjusting certain AC power-generating system components. However, this tester may be adapted to test other AC power-generating system components by using both a special test cable designed for that component and appropriately punched test cards. As an aircraft electrician, you are responsible for the operation and maintenance of the generator control and protection panels. You must know how to operate this test stand properly so as to give you the true operational status of equipment panels. The following discussion will acquaint you with various circuits and components within the test stand.

The test set can test control panels rated at 115/120 volts, 400 Hz, single- or three-phase, and three- or four-wire. The following is a list of the principal tests performed by the T–170 test set:

a. Static regulator.
b. Overvoltage trip time.
c. Undervoltage trip time.
d. Undervoltage trip point.
e. Differential protection.
f. Overcurrent protection.
g. Frequency relay calibration.
h. Exciter protection.
i. Paralleling relay.
j. Overexcitation.
k. Underexcitation.
l. Relay operation.
m. Step-change frequency.
n. Forward and reverse diode.

This test set is designed specifically as a general-purpose test set for all control protection panels. Its maximum output is 100 VA (volt-ampere) per phase. The three-phase voltage is adjustable from 0 to 200 volts, and the single-phase voltage is adjustable from 0 to 150 volts. Fixed and variable DC voltages are available from 0 to 35 volts or from 27 to 63 volts. Figure 2-10 shows a typical T–170 test set. Located at the bottom of this figure you will find a breakdown of the various parts. As you can see, by looking at this figure, the T–170 test set is designed in console form. Use of this design permits easy access to all components through the rear of the console.

Operation of component parts. The input requirement for the test set is 115-volt, 60-Hz, single-phase power with a maximum load of 25 amperes. The input power is connected to the power distribution unit, and the relationship of the subassemblies is shown in the block diagram of figure 2-11.

AC electronic generator. The AC electronic generator (see fig. 2-11) supplies a variable-frequency three-phase and two fixed-frequency single-phase sine wave voltages. This is accomplished by the use of two oscillator sections.

Fixed-frequency section. This section delivers two stable frequencies of 1600 Hz and 400 Hz. A tuning fork and a triod tube are connected to form an oscillating circuit that produces a precise and stable 1600-Hz signal. This signal is fed into a squaring circuit. As a result, the signal is a 1600-Hz square wave with a peak-to-peak amplitude of 200 volts. From this point, the signal takes two paths. One path takes the signal to a clamping circuit. This produces a signal of 10-volts peak-to-peak amplitude which is stabilized against variations. The clamped 1600-Hz square wave is fed to a resonant circuit tuned to 1600 Hz, and the voltage resulting is a 1600-Hz sine wave. This voltage level is controlled by a potentiometer.

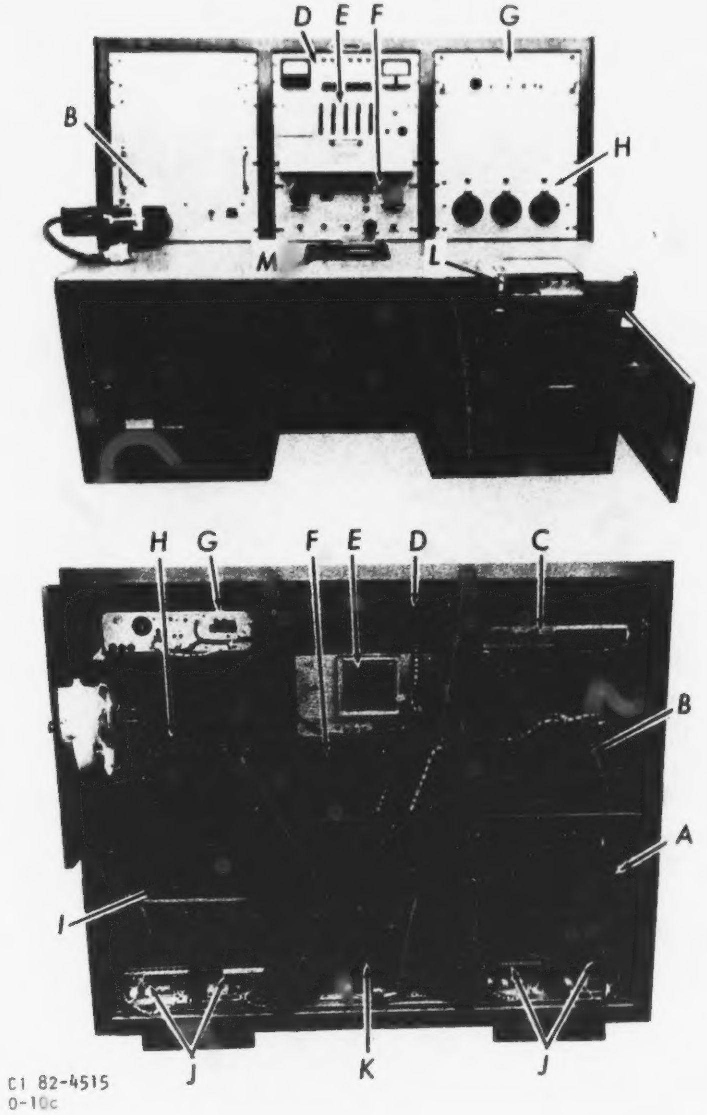
Frequency-divider circuit. The second path taken by the voltage signal is to a frequency-divider circuit that produces an 800-Hz square wave, which is fed, in turn, to a second frequency-divider circuit that delivers a 400-Hz square wave. This signal is sent through a clamping circuit that produces a 400-Hz square wave which is stabilized against circuit variations. The clamped 400-Hz square wave is fed to a resonant circuit tuned to 400 Hz, and the voltage resulting is a 400-Hz sine wave. This voltage level is also controlled by a potentiometer.

Variable-frequency section. This section produces frequencies in two ranges, 375 to 420 Hz and 300 to 500 Hz, that are controlled by three dials on the front panel. Two dials are for the 365- to 420-Hz range and one for the 300- to 500-Hz range. Basically, this oscillator consists of five plug-in DC operational-type amplifiers, suitably arranged with resistor and capacitor networks to form an oscillator.

In order to control and regulate the amplitude of oscillation, a regulator circuit is included in the oscillator which allows the amplitude to be set anywhere in the range of from 9 to 14 volts by manual adjustment of a potentiometer. This maintains the amplitude nearly constant throughout the frequency range of the oscillator by comparing it to a DC reference voltage. The oscillator voltage is rectified to produce a DC reference voltage.

Variation of the oscillation frequency is achieved by simultaneously varying a pair of resistors in the oscillator circuit. These are potentiometers attached to the frequency dials. The output voltages which deliver four voltage signals of equal amplitude (one is single-phase and the others form into a three-phase voltage output) are connected to the four power amplifiers.

Power amplifiers. Each of the four power amplifiers (see fig. 2-11) is divided into a voltage-amplifying section and a power-amplifying section. Each section is supplied by a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A. Power Distribution Unit
B. Programmer and Relay Control Center
C. Control DC Power Supply
D. Indicator Unit
E. Electronic counter.
F. Voltage-Control Unit
G. Converter Voltage-to-Frequency
H. AC Electronic generator
I. DC-Amplifier Power Supply
J. Power Amplifier.
K. Power Supply DC Amplifiers
L. Recorder Unit
M. Card Switch

Figure 2-10. T-170 test set.

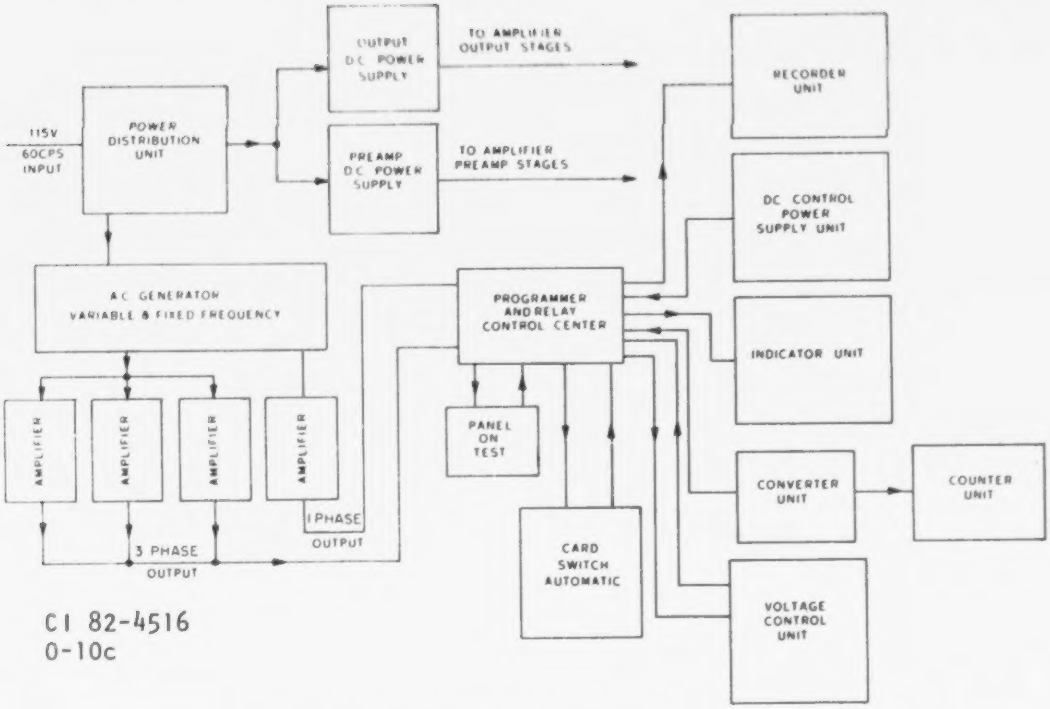
115V
60CPS
INPUT
POWER DISTRIBUTION UNIT
OUTPUT DC POWER SUPPLY
TO AMPLIFIER OUTPUT STAGES
PREAMP DC POWER SUPPLY
TO AMPLIFIER PREAMP STAGES
RECORDER UNIT
DC CONTROL POWER SUPPLY UNIT
AC GENERATOR
VARIABLE & FIXED FREQUENCY
PROGRAMMER AND RELAY CONTROL CENTER
INDICATOR UNIT
AMPLIFIER
AMPLIFIER
AMPLIFIER
AMPLIFIER
PANEL ON TEST
1 PHASE
OUTPUT
3 PHASE
OUTPUT
CONVERTER UNIT
COUNTER UNIT
CARD SWITCH AUTOMATIC
VOLTAGE CONTROL UNIT
CI 82-4516
0-10c

Figure 2-11. Block diagram of the T-170 test set.

separate power supply. Each amplifier has its own filament power supply. A cooling fan is mounted on each amplifier chasis. One of the power amplifiers is used to amplify the single-phase output, and the other three form and amplify the three-phase output from the AC generator. These oscillator output voltages are fed to the voltage-amplifying section through a resistor network which determines the gain of the signals. The voltages are amplified enough to drive the power-amplifying section.

The power-amplifying section is a push-pull configuration using two power triode tubes. The amplifer develops 100 VA under reactive load without exceeding the power rating of the tubes. The output impedance of each power amplifier is one ohm.

Amplifier power supply. The power for the amplifier units is supplied by two power units (see fig. 2-11). One unit supplies power for the preamplifier stages, and the other power supply provides power for the amplifier output stages. Both units have 115-volts, 60-Hz input and a filtered DC output.

Power-distribution unit. This unit provides the means of distributing the input power to the various units of the test set. The power supplied to the output DC power supply for the amplifier-output stages is fed through a time-delay circuit that allows the filaments to become properly heated before the plate voltage is applied to the amplifier-output tubes. Otherwise, damages to these tubes might result. Another power source coming from the power distribution unit provides 26 volts, 60 Hz for the start-test indicator located in the programmer and relay control center.

Programmer and relay control center. This unit, as shown in figure 2-11, contains relays and transformers which form a connecting point for the card switch, indicator unit, voltage-control unit, and power supply.

Card switch. This switch is an electromechanical device set to be used in a particular test. Individual sets of contracts are opened by means of a punched card placed in the switch. The sets of contacts are opened when a hole is present in the card and the switch mechanism is operated. The switch mechanism is activated by a solenoid located at the rear of the card slot. Placing the punched card fully into the slot automatically operates the card switch. Thus, the circuits that are not needed in a particular test are made inoperative by the test card.

Indicator unit. This unit includes a set of six numbered indicator lamps that indicate the circuit of the panel under test. A DC voltmeter and DC ammeter are also provided.

Voltage-control unit. This unit contains most of the operating controls needed during test procedures. Two voltage controls are provided. One is a single-phase variable transformer which is used to control the DC voltage level on the AC bias voltage level. The other, a three-phase variable transformer, is used to control the three-phase AC voltage. The unit also contains a PHASE-SELECTOR switch that permits monitoring each of the three phases of the AC voltage individually. Additional switches are provided to control the panel under test. The trip switch and rest switch apply DC voltage to the trip and reset coils of the generator control realy. The set-test switch, in the SET position, arranges circuits that permit the presetting of various voltage conditions which are then applied to the control panel when the switch is placed in the TEST position.

Control DC power supplies. This unit contains four separate DC supplies used for control purposes. One provides biasing for the timing circuits. This supply

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operates from a 60-Hz AC source. Another is used to operate indicator lamps and relays. A third is used to supply control power to the panel under test. The last one is a variable DC supply which may be operated from either a regulated 60-Hz or 400-Hz input. This supplies varible control power to the panel under test.

Recorder unit. This direct-recording oscillograph is equipped with two active galvanometers and two static traces used as reference lines. One channel may be used to display the output of the frequency-and-load controller to the magnetic governor trim coil, and the second channel may be used for timing to show the application of step changes during transient tests.

The T–170 tester is used in testing the frequency-and-load controller unit. The preliminary settings of all controls should be at their initial positions. In testing the load-division circuit, the applicable punchcards are inserted in the punchcard receptacle. Other circuits in this unit that may be tested are:

- Frequency-control circuit.
- Output linearity and gain of the frequency-control circuit.
- Load-division null potentiometer adjustment and gain potentiometer setting.
- Synchronizing relay test.

Troubleshooting and repair. If the tester fails to operate for any reason, a systematic procedure should be used to troubleshoot it. Naturally, the first place you would check would be the power source. Then you would check the circuit protection devices on the tester. From there, you would have to go into the tester. You will only disassemble the tester to the extent necessary to repair or replace the defective part or to correct a faulty condition that has been found. Any repair or overhaul required should be done in accordance with the applicable TO. A troubleshooting chart is located in most TOs to aid you in finding the trouble.

Exercises (225):

1. What can be tested/adjusted on the T–170 tester?

2. What is the power requirement of the T–170 tester?

3. What frequencies are produced from the fixed frequency section?

4. How many frequency ranges are in the variable frequency section and what are they?

5. What sets the T–170s circuits up for testing of components?

6. What DC voltages are available from the T–170 tester?

226. Cite the functions and operational characteristics of the MC–2 test stand.

MC–2 Tester. The MC–2 test stand, shown in figure 2-12, is designed for field-testing constant-speed transmissions, their 400-Hz AC components, and certain AC generators. The test stand uses power from a three-phase line operating at a voltage of either 220 or 440 volts line-to-line at a frequency of 60 Hz. The power unit is provided with dual heads or power take-off shafts, the speeds of which are proportional to each other through the speed ranges. The low-speed head may be varied from 2000 to 7500 rpm, and the high-speed head may be varied from 2400 to 9150 rpm.

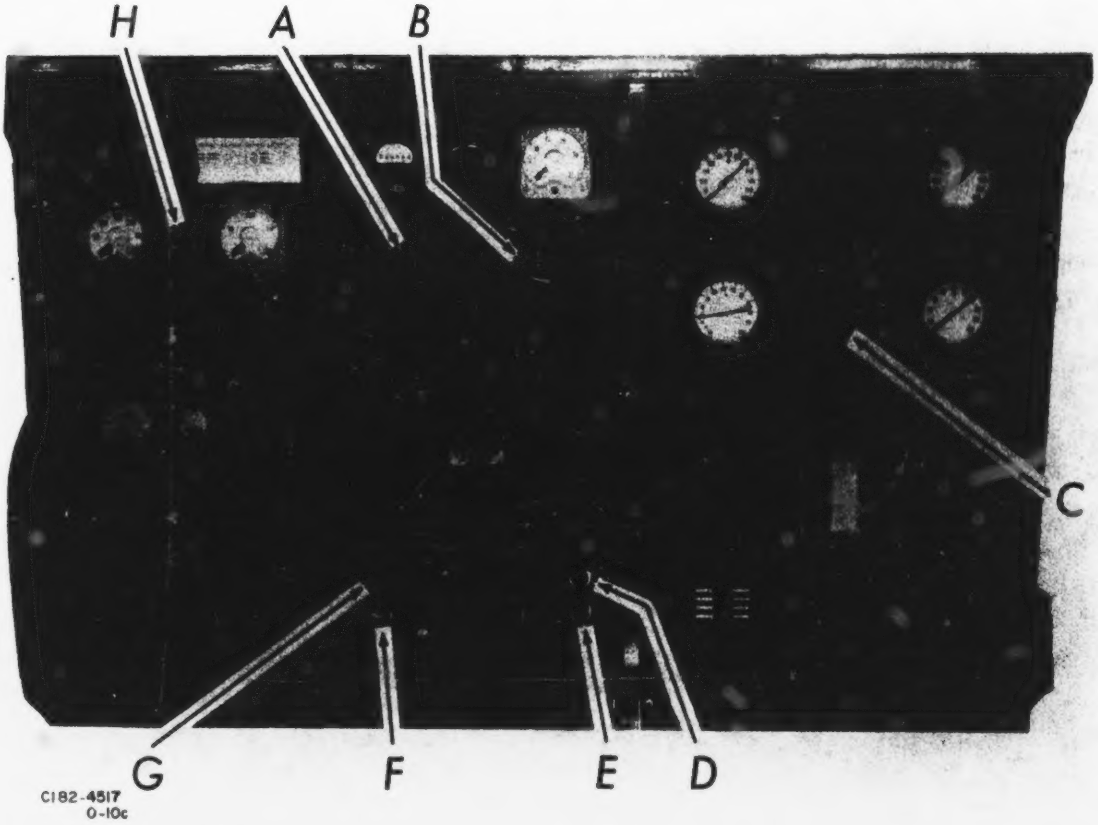
Components. This test stand consists of a shield, skid-type base, control console, variable-speed main prime mover, and instrumentation and controls.

All components of the test stand are accessible for maintenance and adjustment through the doors and the removable panels. The controls and instrumentation on the control console are arranged on two doors and one panel, as shown previously in figure 2-12. They are a 400-Hz AC control door, a 60-Hz AC and speed control door, and a hydraulic panel. A chronotachometer containing two rpm indicators, two revolution counters, and a minute counter is located on the 60-Hz AC and speed-control door.

Before using the field test stand for testing an aircraft system, the proper adapter kit must be installed. There is a different adapter kit for each system. You will find instructions for installing the various adapter kits, as well as for mounting transmissions and AC generators, in the applicable technical order. All wiring harness and other components necessary for adapting the test stand to an aircraft system are included in each kit.

Operation. Always refer to the applicable technical order for operating instructions. When the 5-hp unit "start" prime mover produces maximum accleration, then the 75-hp unit "run" prime mover may be engaged. There will be an immediate speed increase to approximately 2000 rmp on the low-speed rpm indicator (item B, fig. 2-12) on the chronotachometer, and to 2440 rpm on the high-speed, as shown by the high-speed rpm indicator (item A, fig. 2-12). The 75-hp INCREASE button (item D, fig. 2-12) may then be used to bring the speed of the prime mover to the desired rpm.

When the prime mover speed has reached the minimum rpm necessary for the system being tested, the AC generator may be excited. Exciting the AC generator automatically places the AC generator on the bus for some applications. When this is the case, the LOWER two synchronizing lights



A. High-Speed rpm indicator
B. Low-Speed rpm indicator
C. Charge Oil Reservoir Oil Sight Gage
D. Main Prime Mover Increase Button
E. Main Prime Mover Decrease Button
F. Start Prime Mover Decrease Button
G. Start Prime Mover Increase Button
H. Synchronizing Lights.

Figure 2-12. MC-2 test stand.

(item H, fig. 2-12) will come on with a bright steady light, and the top synchronizing light will *not* light. If all the synchronizing lights begin flashing on and off in rotation, it indicates that the AC generator is excited but not on the bus. Pressing the MANUAL C-B CLOSE button will place the AC generator on the bus. A load bank connected to the bus will check the AC generator under load.

Operator Maintenance. Maintenance for the MC-2 test stand consists of periodic cleaning, lubrication, and replacement of oil filters. A monthly check also should be made for loose connections, loose bolts and nuts, dust, and worn or damaged parts.

When you are looking for damaged parts, remember that the only parts likely to become worn or damaged are varibelts and gears. Worn gears should be replaced by authorized personnel only. After operating the test stand, you should inspect it for leaks in the hydraulic system which could cause damage to varibelts or other components.

Service. Varibelts and unlined faces of varidiscs should be kept clean and free from any grease or lubricant. If any grease is found, remove it with a clean cloth and lacquer thinner. Never use gasoline on varibelts. The entire test stand should be dusted regularly to remove all dirt and foreign particles. Like most machinery, the regular inspection of the MC-2 test stand oil filters is of prime importance. After 25 hours of test stand operation, inspect both the scavenge and charge line oil filters. Replace the oil filter elements if they are contaminated. An indication of 30 psi or greater on the scavenge pressure gage could indicate a buildup of sediment in the scavenge oil element. The scavenge oil element should be inpected at this time, regardless of operating time.

All lubrication of the test stand, control motors, and prime movers should be done as directed by the applicable technical order. This will not only extend the service life of the equipment, but will save manhours used for repair. When troubleshooting the test stand, make sure you use the technical order at all times and observe all safety precautions.

Exercises (226):

1. What is the MC-2 designed to test?

2. When the MC-2 is first started, at what speed should the low-speed head be operating?

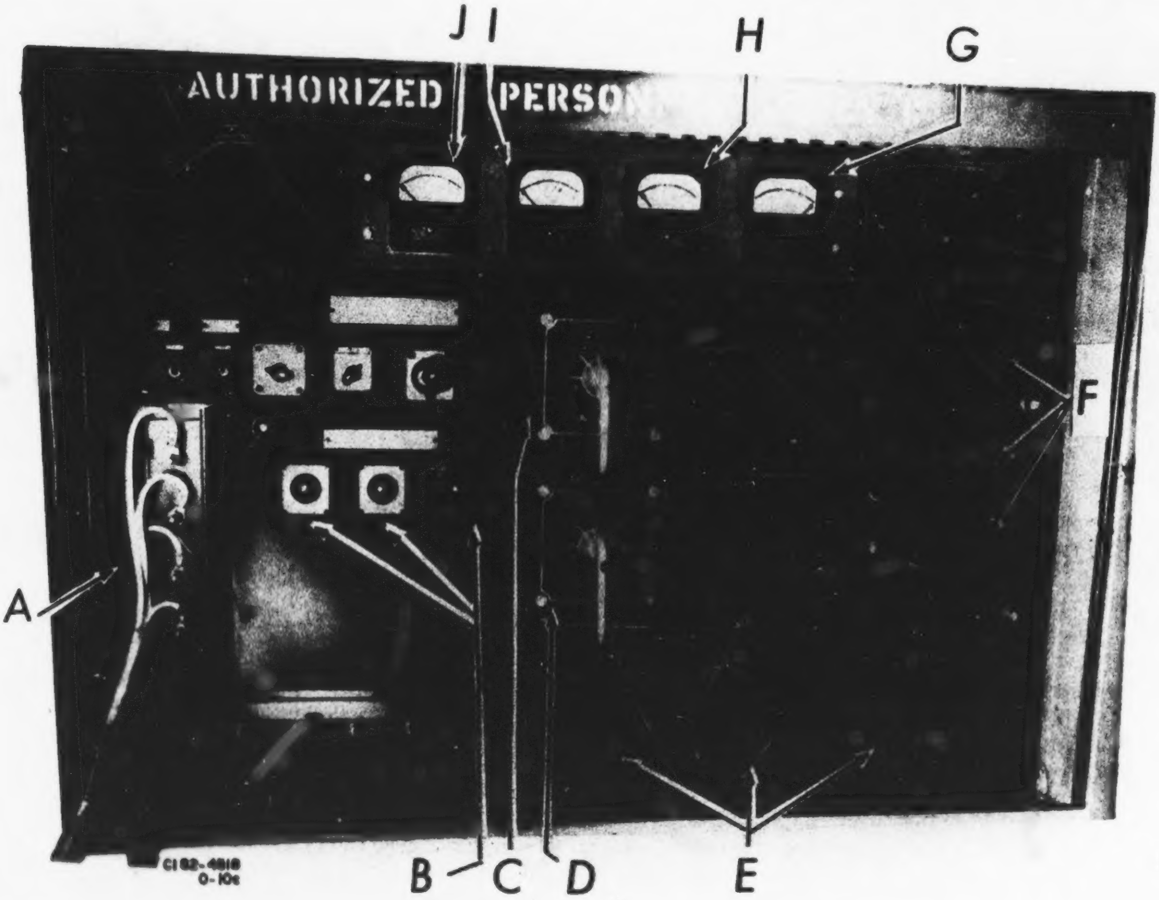
3. What item of test equipment is designed for use with the MC-2?

4. If a defect developed in the MC-2, where would you find information to help you locate the trouble?

227. State the purpose of the A-1 load bank and how to use it.

An A-1 load bank is used with the MC-2 test stand. The load bank provides all of the necessary loads to test AC generators.

A-1 Load Bank. This tester is primarily designed to provide a means for load testing aircraft-type four-wire AC generators with 120/208 volt, three-phase, 400-Hz rating. The load bank is fully equipped to apply either resistive



A. T1, T2, T3, and N Terminal Posts
B. Reactor Load-Control Rheostats
C. Ammeter Range Selector Switch.
D. Wattmeter Range Selector Switch
E. Resistive Load Control Rheostat
F. Resistive Load Control Switches
G. Power Factor Meter
H. Wattmeter
I. Ammeter
J. Voltmeter

Figure 2-13. A-1 load bank.

loads up to 60 kW or reactive loads up to 40 kVAR, as required by the test specifications of the manufacturer. The complete assembly consists primarily of an all-steel housing into which are assembled all components required by the load bank assembly for carrying out required tests. Instrumentation, connection, and controls are conveniently grouped on a common instrument panel within easy reach when you are standing in a normal position in front of the unit. The entire unit has been designed to fit on the bed of a type K-1 trailer.

Circuit operation. The tester consists of a number of electrical components whose functions are directly related and closely coordinated. The entire electrical supply is from the AC generator under test, and no external source of power is required. We will discuss the circuit operation as a series of subcircuits for the sake of clarity. In the following paragraphs, refer to figure 2-13 for reference to items.

The loading circuit is based on three-phase operation, with each phase individually loaded. Since the normal operational load of the test component probably never will be purely resistive, means are provided to apply a total reactive load up to 40 kVAR. (Note items A and B of figure 2-13.)

The three phases of the AC generator may be worked into a purely resistive load. The load is variable up to 60 kW with 20 kW in each phase. The loading of each phase is completely independent of the other two phases. See the resistive load control in items E and F of figure 2-13.

The ammeter circuit provides you with a means for measuring the current flow in each of three phases and consists primarily of the ammeter (item I), the three-section range selector switch (item C), the PHASE SELECTOR switch, and three current transformers.

The wattmeter circuit provides a means for measuring the power produced by the AC generator. The circuit consists of three current transformers, a wattmeter range selector switch (item D), a wattmeter (item H), a WATT-VARS switch, a phase shift transformer, and a resistance box.

A voltmeter circuit is provided so that the line-to-line voltages and the phase voltages can be measured. It consists of a voltmeter (item J), a selector switch, and a multiplier.

The power factor meter circuit provides you with a means for measuring the amount of phase shift between the line voltage and the line current. The circuit consists of the power factor meter (item G) and voltage-dropping resistor box.

Fans are provided to prevent overheating of the load bank components during tests. The circuit consists of the cooling fans, a manual thermostat switch, two condensers, and the thermostats.

The dry disc rectifier supplies the DC power needed to operate the control circuit. This circuit provides both the power used in varying the reactive load on the AC generator and the power for the various relays.

Connections. The instrument panel is equipped with eight terminal posts to permit you to make connections with the AC generator to be tested and to permit the connection of an external load when necessary. The connections from the AC generator are to the input terminal posts T1, T2, T3, and N. Since the AC generator is a "y" or star type, the N post is the neutral or ground wire and is grounded to the cabinet assembly ground connection within the load bank. The external load terminal posts 1, 2, 3, and N permit you to connect an external load to the AC generator while using the load bank instruments for measuring the performance of the AC generator and the load applied. Always refer to the applicable technical order for operation instructions. Never attempt to make connections to an AC generator or to a load bank terminal while the AC generator is in operation. Never touch any terminal posts with the AC generator in operation.

Preliminary adjustment. Before you are ready to operate the load bank, you must perform these procedures:

a. Open the exhaust door on top of the unit. This is very important. Failure to do this can cause the unit to overheat to the extent that the unit could be damaged. Open the door covering the control panel and swing it up onto the top of the load bank. Latch the door in this position with the latch provided.

b. Check to see that the voltmeter, the ammeter and the wattmeter read zero. A meter reading of other than zero indicates a faulty meter.

c. Place all ON-OFF switches in the OFF position. Place the range selector switch in the 250-AMP position.

d. Open the cable access door and connect the 3-phase, 4-wire, 120/208 volts, 400-Hz, AC generator to the load bank input terminals.

e. The phase sequence indicator lights must indicate a 1-2-3 phase sequence for proper power factor meter indication and fan rotation.

f. With the phase-to-phase—phase-to-neutral toggle switch in the phase-to-phase position, rotate the voltmeter switch through all of its positions. The voltmeter must read approximately 208 volts in all positions.

Troubleshooting and repair. If the load bank fails to operate for any reason, a systematic procedure should be used to troubleshoot it. Naturally, the first place you would check would be the power source. From there you would have to go into the load bank. Any repair required should be done in accordance with the applicable TO. A troubleshooting chart is located in most TOs to aid you in finding the trouble.

Exercises (227):

1. What is the primary purpose of the A-1 load bank?

2. In what position do you set the range selector switch during preliminary adjustment?

3. What should you check to measure the phase shift between the line voltage and line current?

DC Generator System

IN THIS CHAPTER we discuss DC generator systems. The information you learn from this chapter will be of great value to you when performing everyday duties as an electrician. You should always refer to the proper technical order for a particular generator system; however, the discussion here will provide you with the background knowledge required to troubleshoot, test, and maintain any DC generator system. A typical generator system consists of a generator, voltage regulator, overvoltage relay, field control relay, and reverse current relay. These are the components we will discuss.

The operation of most electrically operated equipment in an aircraft depends upon energy supplied by a generator. A generator is a machine that converts mechanical energy into electrical energy by electromagnetic induction. In aircraft using DC electrical systems, you will find one or more DC generators supplying this power.

To keep the aircraft in a flying status, it is necessary that you repair malfunctions in the shortest possible time. To do this, you must be familiar with the various components of the DC generator system and how they operate. Knowledge of the following will help you be a better specialist and, at the same time, keep the aircraft flying.

3-1. DC Generator

The simplest generator field is built like the drawing in figure 3-1. Two electromagnets are mounted in a circular iron frame called a *yoke*. These electromagnets are wound so as to produce opposite polarity. Notice how the magnetic circuit is entirely in iron except at the center between the poles. This area between the pole pieces is the only part of the field outside the iron.

The yoke, its pole pieces and windings, and the field it produces make up the generator's primary circuit. The secondary circuit is a coil wound on an iron core. The coil and iron core are mounted on a shaft and is called the generator's armature. Figure 3-2 shows a typical armature. To make the generator complete, the armature fits into the area between the pole pieces. The yoke of the generator stands still and thus the field of flux (magnetic lines of force) is steady and stationary. The armature shaft is rotated by a source of mechanical power and, as the armature is rotated, the conductors of the coil cut through the magnetic field. In the simplest, as well as in the most complex systems, armature conductors cutting flux produce an induced voltage. As you know, rotating coils produce alternating voltage. This will never work because we wanted DC. What shall we do then? We should not forget one more part of the armature, the commutator. This changes the AC produced by the rotating coils to DC, which is delivered to the generator terminals. Now that you have reviewed the construction of a simple generator let's move on.

228. Cite fundamentals of three basic types of DC generators.

Types. In this section, we will briefly discuss the (1) series-wound, (2) shunt-wound, and (3) compound-wound generators. We will start with the series-wound generator.

Series-wound generator. In the series-wound generator, the field coils are connected in series with the armature. The current in the load, which is connected externally, also flows through the field coils. Since the magnetic field strength is proportional to the load current, a varying load would result in a varying output voltage. In other words, as the load increases, the terminal voltage increases, and as the load decreases, the terminal voltage decreases. Because the electrical and electronic equipment installed in aircraft requires a constant voltage, the series-wound generator cannot be used.

Shunt-wound generator. A shunt-wound generator is one that has its field coils connected in parallel with the armature terminals. The shunt-wound generator produces the greatest terminal voltage under no-load conditions. As the load increases, more current flows through the load and less through the field, and the terminal voltage decreases. Therefore, as the load increases, greater current flows through the external load and the armature. This greater current through the armature increases the voltage (IR) drop across the armature and reduces the terminal voltage. The reason is that a larger quantity is subtracted from the no-load terminal voltage and the difference or terminal voltage under load is decreased. This smaller voltage sends less current through the field, and the resulting decreased magnetic field strength reduces the output voltage. For load-current changes within the design range, the drop in output voltage with increasing load current is not too severe for certain aircraft requirements.

Compound-wound generator. A compound-wound generator has both a series field and a shunt field. The shunt field coils are connected across the armature, as in the shunt-wound generator previously discussed. The series winding is connected in series with the load. The series windings are wound onto the pole piece so that the magnetic flux they produce is added to the flux produced by the shunt winding. Therefore, since the series field is in series with the load, the same amount of current flows in the load circuit as in the series field windings. When the load increases, more current flows through the series field windings, causing an increase in the strength of the field in

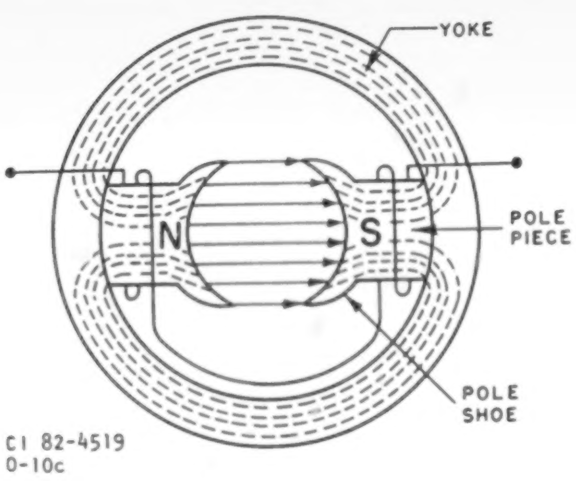


Figure 3–1. Generator magnetic circuit.

which the armature rotates. This action tends to increase the generator output. The shunt winding acts as it does in a regular shunt-wound generator; i.e., the terminal voltage tends to decrease as each load increases; the two actions are opposite in effect and the terminal voltage remains the same. This is exactly what you are looking for in a generator. In almost every case where a constant voltage under varying loads is needed, you will find a compound-wound generator used.

Exercises (228):

1. a. In the series-wound generator, what two items or components are connected in series?

   b. Current, in the field coils of the series-wound generator, also flows through what?

   c. As the series-wound generator's load increases and decreases, what is the effect on the generator's output voltage?

2. In the shunt-wound generator, what two items or components are connected in parallel?

3. How is the generator, which is found most favorable for aircraft usage, wound?

4. In a compound-wound generator, what is the relationship of the field coils to the load?

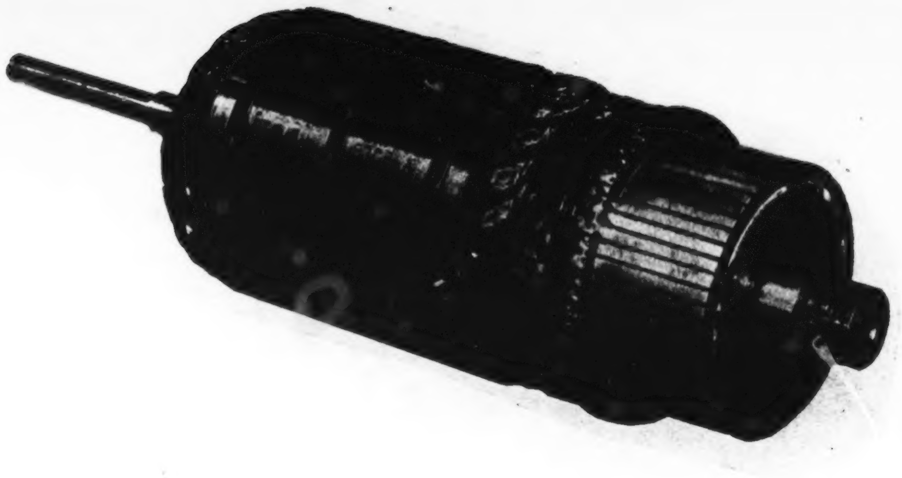
229. Specify what you look for in maintaining a DC generator.

Inspection and Maintenance. When you are working in a maintenance area where generators are disassembled, you may perform various electrical tests on the components of each generator to determine their serviceability. For the exact specifications on components of a particular generator, refer to the overhaul instructions technical order for that particular generator. This information is important when inspecting an aircraft, because if you know the standards of a good unit or component, you can more readily identify substandard performance, i.e., components not performing to the desired standard.

Commutator. The commutator is constructed of a large number of individual copper segments, each of which is electrically insulated from the others, and from the other parts of the armature by mica insulation. As the brushes wear away during the service life of the generator, the carbon dust may settle momentarily into the spaces between the commutator segments; and as the armature rotates, most of this dust is thrown out of the slots due to centrifugal force. If oil or grease should get on the surface of the commutator, it might mix with the carbon dust and cause it to collect and stick in the slots between segments. If this condition did occur, the carbon dust particles might adhere to the walls of the slots so that eventually a short circuit would develop between the various commutator segments. This short-circuited condition would cause the output voltage of the generator to be adversely affected.

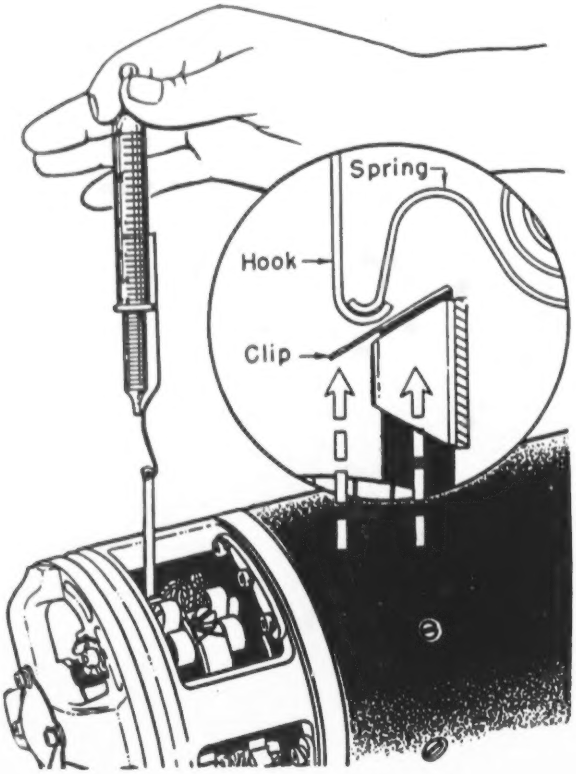
You are familiar with the color of a new copper penny, and that is what you may expect the copper commutator to look like at all times. However, this is not correct. Due to the oxidation of the copper and the operation in contact with the carbon brushes, the color of a normally operating commutator is a chocolate brown. Any burned spots along the side of the commutator segment indicate that some brushes are not properly fitted to the commutator or that trouble is about to develop. You may remove burned spots by placing a strip of sandpaper, the width of the commutator with the sanded side down, around the commutator and sliding it back and forth. Take care not to work so long on a burned spot as to cause the surface to develop a flat spot. After you complete the operation, direct an airstream through the brush assembly to remove any loose, abrasive, or carbon dust.

Brushes. A spring device holds each brush in contact with the commutator. You should check the brush-spring pressure periodically in accordance with instructions contained in the applicable TO on the generator. Figure 3-3 shows you how to check the tension, using a small spring scale. The proper time to read the scale is when the spring lever is about one-sixteenth of an inch off the brush. You will have to make certain of the exact spring pressure for each particular generator from the pertinent technical order.



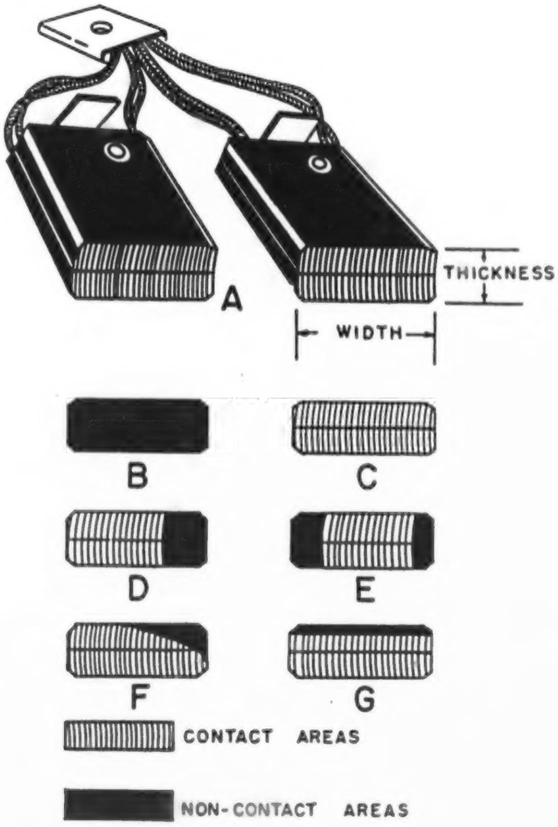
CI 82-4520
0-10c

Figure 3–2. Generator armature.


Spring
Hook
Clip

CI 82-4521
0-10c

Figure 3–3. Checking brush springs.


A
THICKNESS
WIDTH
B
C
D
E
F
G
CONTACT AREAS
NON-CONTACT AREAS

CI 82-4522
0-10c

Figure 3–4. Correct and incorrect brush fits.

Too much spring pressure increases the friction between the brushes and the commutator and, consequently, increases the wear on the brushes. Insufficient contact pressure may lead to jumping brushes with poor output and which could possibly cause burning and damage to the commutator.

When you lift the brush springs to remove the brushes for inspection, use a small hook made from a piece of wire instead of your finger. This prevents the possibility of the spring slipping from your grasp and slamming down against the brush, which could cause the brush to crack, chip, or otherwise be made unfit for further use.

As you remove each brush from its holder, examine it carefully for cleanliness and length. Examine the contact face for correct seating on the commutator. If the brush holders need cleaning, wipe them with a cloth moistened with an approved cleaning solvent. Never immerse carbon brushes in cleaning solvent.

The length of the new brushes varies from manufacturer to manufacturer; so does the method of measuring the length of the generator brushes. There are as many different minimum lengths of brushes as there are generators, so you must always look in the applicable technical order for the minimum brush length for a particular generator. After some experience, you learn approximately how much the brushes wear between inspections, and then you are prepared to change the brushes before they reach their minimum lengths.

The correct seating of the brushes on the commutator is very important. You can readily check this by looking at the contact face of the brush. Properly seated brushes should show contact 100 percent across the brush thickness for at least 70 percent of the brush width, as shown in figure 3-4, item A. In figure 3-4 the solid black areas represent noncontact areas, and the portion of the brush contact face that is shown with light lines represents the area of the brush that is in contact with the commutator. Figure 3-4, item B, shows the end view of a new brush which must be seated to the commutator after installation. Figure 3-4, item C, shows a brush that is showing 100-percent contact across both the thickness and the width of the brush, which is a highly desirable condition. Items D and E of figure 3-4 show brushes that are making 100-percent contact across the brush thickness for at least 70 percent of the brush width. Items F and G of figure 3-4 depict conditions which are not acceptable because the brushes are not making 100-percent contact across the thickness of the brush.

When new brushes are installed in a generator at a factory or depot, they are allowed to run for up to 1 hour at no-load and, in this way, wear in by themselves. This cannot and should not be done on generators that are installed on aircraft because the brushes may be called upon to conduct current as the generators start turning. Unless the brushes are making proper contact with the commutator, serious arcing might occur which could damage the commutator.

Figure 3-5 shows how a new unfitted brush appears as it rides on the surface of the commutator, and directly opposite, how a properly fitted brush appears. To achieve this effect when you install new brushes, place a strip of No. 000 or No. 0000 sandpaper (the width of the commutator) under the brush, with the sanded side next to the brush, and then withdraw it from under the brush in the normal direction of rotation of the armature. Do not use emery paper or crocus cloth for this operation because they are metallic materials, and should particles of the material become imbedded in the brush, arcing and pitting of the commutator will result. Do not slide the sandpaper back and forth under the brush. After you have withdrawn the sandpaper, lift the brush from the commutator and reinsert the sandpaper under the brush. As the brush is held again against it, withdraw the sandpaper in the normal direction of rotation. Continue this process until the brush fit meets the minimum requirement of 100-percent contact of the brush thickness for at least 70 percent of the width of the brush. After you have completed this procedure, normal generator operation will complete the operation of fitting the brushes to the commutator.

Armature. The first of the three electrical tests for the armature is the check for grounds. On all of the conductors used in the armature, the only insulation used is a baked coating of insulating varnish. If this insulating varnish should chip or otherwise be worn away, there is a possibility that one or more of the armature conductors may be touching some part of the iron core of the armature. This test is also a check of the insulating value of the mica between the commutator segments and the main body of iron of the armature assembly. This check is called a *high-potential test*, in that a 110-volt or a 220-volt AC test lamp is used. Place one of the test lamp leads on the armat. shaft (see figure 3-6) and the other lead on the commutator riser. Now move the lead, that is touching the commutator, back and forth to make contact with several segments. If the test lamp lights, there is a ground, and the armature assembly must be discarded. Because of the method used in winding armatures, you do not necessarily have to perform this check around the full circumference of the commutator; for if any one conductor of the armature winding is grounded, a circuit will be completed for the test lamp.

The second check is the growler, or the short-circuit check. The typical growler consists of a laminated U-shaped soft iron core with the open ends upward. An electrical winding is normally enclosed within the base of the unit. A growler operates only when connected to a source of alternating current. The unit is so constructed that when an armature is placed within the open ends of the electromagnet, a vibration is caused between the armature core and the growler poles, resulting in a buzzing or a growling noise. This noise is no indication of the general condition of the armature, for every armature, good or bad, will have the growling sound when placed on the unit with the electrical circuit completed.

The combination of an armature and a growler is similar to a transformer; the core of the armature in contact with the pole pieces of the growler forms an all-metal path for the magnetic circuit. The winding of the growler becomes the primary of the transformer, and the winding of the armature becomes the secondary, in which a voltage is induced by the alternating action of the magnetic field developed in the iron core.

To check an armature for short circuits, hold a piece of a hacksaw blade loosely on the top of the armature and slowly move it all the way around the armature, turning the armature assembly on the growler as required. Normally

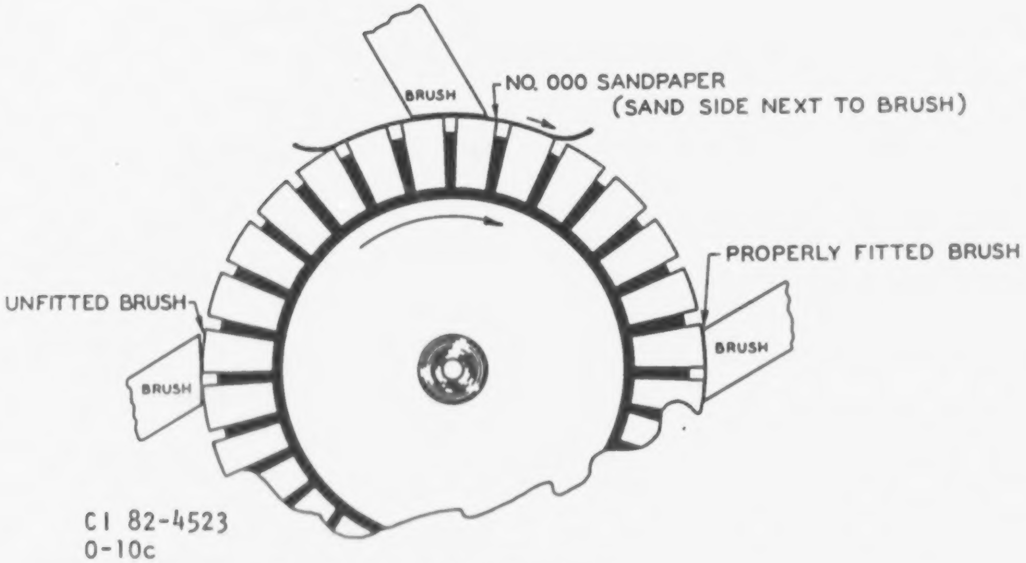


Figure 3–5. Seating brushes with sandpaper.

there is a voltage developed in the windings of the armature, but because of its construction, no current will be flowing within the armature. If the hacksaw blade should be attracted to the armature at any point and buzzes, it indicates that there is a current flowing in the conductors that are beneath the blade, and therefore a short circuit must exist within the armature. If there is a short circuit, the armature assembly must be discarded, unless the trouble is due to solder that is bridging the commutator risers. This trouble is usually reparable.

You can safely perform the third and final check on armatures only after the previous two tests have revealed no troubles. The check for open circuits in an armature can be made in two ways: (1) with the AC ammeter on the growler and (2) with a hacksaw blade.

To check the armature for open circuits with the ammeter on the growler, place the armature on the growler and turn it on. Place a special commutator testing probe that has two contact fingers (contact points) so that each of the contact fingers touch two adjacent segments on the commutator. Rotate the armature and continue the test by placing the contact fingers on each succeeding pair of segments. The ammeter will register zero if the armature contains an open winding when the contact fingers are placed on the segments connected to that winding. If the armature is functional, the ammeter will register a value as specified in the TO for the generator armature being tested.

To check the armature for open circuits with a hacksaw blade, place the armature on the growler and turn it on. As the armature is slowly rotated, short circuit each segment of the commutator with the adjacent segment, using the saw blade. A strong flash or spark should be obtained between each pair of adjacent segments if there are no open coils in the armature. If no spark is seen, the armature has an open coil.

If no reading on the ammeter is obtained or no spark at the commutator is seen, check the connections at the commutator riser for security. If the trouble is not at the soldered connection to the riser, the armature should be discarded.

Field. First, give the field assembly a high-potential test, using either a 110-volt or a 200-volt test lamp (see fig. 3-7). Place one test lamp lead on an unpainted part of the generator frame; then, touch the other lead to each of the terminals A, B, D, and E. The identification of all aircraft generator terminals is standardized. The terminals are identified by the letters A, B, D, and E, both for simplicity and standardization. Terminal A is always the shunt field terminal, terminal B is always the generator positive terminal, terminal D is always the generator equalizer terminal (to be discussed later), and terminal E is always the generator negative terminal. If the lamp lights, there is a ground in the circuit and the field assembly must be discarded unless the trouble is at the generator terminals and is reparable.

Next, check the shunt field circuit resistance with an ohmmeter. To do this, connect one ohmmeter lead to the E terminal and the other to the A terminal. The shunt field resistance varies from one generator model to another and between manufacturers. Therefore, you must obtain specific information for a particular generator from the applicable technical order. A resistance lower than the minimum specified may indicate a short circuit in the shunt field, and a resistance higher than the maximum allowable may indicate an open circuit or a loose connection. If the resistance is too low or too high, you must discard the field assembly unless you can easily find the trouble and can repair it.

Exercises (229):

1. What may occur if a few drops of oil are spilled on a DC generator's commutator?

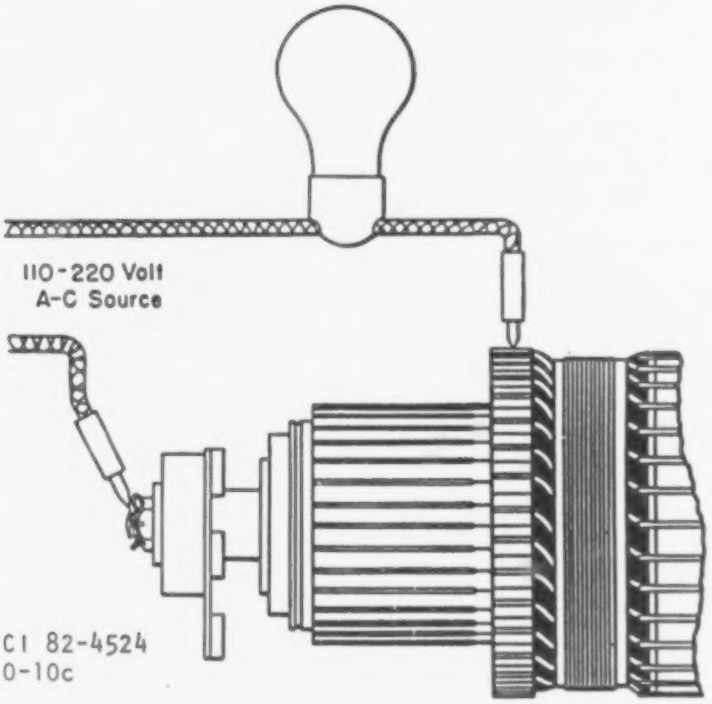

110-220 Volt
A-C Source
CI 82-4524
0-10c

Figure 3–6. Checking armature for grounds.

2. What type of maintenance is called for if the commutator is a chocolate brown color? Explain.

3. What are the effects of incorrect brush-spring pressure?

4. What is the minimum contact surface on a properly seated brush?

5. What is most commonly used for seating generator brushes?

6. What is the indication of a grounded armature?

7. In the growler test, what does a buzzing hacksaw blade indicate?

8. When making a generator field test, what indicates a grounded circuit?

9. What indication does an open armature give in the growler test?

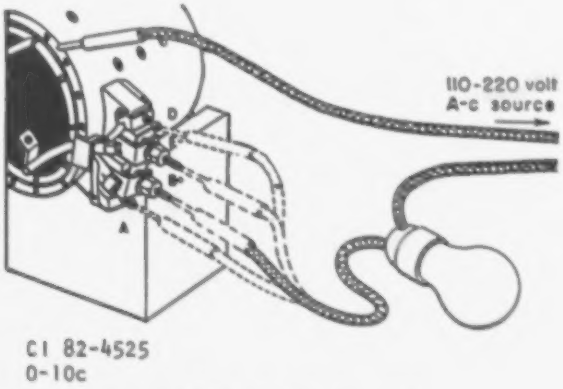

110-220 volt
A-c source
D
B
A
CI 82-4525
0-10c

Figure 3–7. Checking field for grounds.

3-2. DC System Components

Now that you are familiar with the characteristics of DC generators, it is only natural that the next topic should be that of the various control and protective devices that are in all DC generator systems.

For many reasons, you must be familiar with the operation and characteristics of these components. For example, when troubleshooting DC generator systems, you must know how the various components function so that you can distinguish between troubles caused by the generator and those that are caused by the voltage regulator or other controlling devices. Another reason for learning about these components is that you are required to overhaul or repair many of them. After you have performed the necessary maintenance on these components, you will have to bench test and calibrate them for proper operation.

Most of the electrical equipment installed in an aircraft is designed to operate normally within a specified range of voltages; variations from these limits cause an undesired change in the characteristics of the equipment. If for some reason the generator were to produce an excessively high voltage, much of the equipment in operation at that time could burn out. To prevent this from occurring, various control and protective devices are incorporated into the generator circuits. These devices disconnect the generator from the distribution system whenever the output voltage rises above or drops below a predetermined value. These control or protective devices consist of such units as a voltage regulator, a reverse current relay, an overvoltage relay, and the field control relay. We will begin our discussion with the voltage regulator.

230. Cite characteristics of the voltage regulator.

Voltage Regulators. The purpose of the voltage regulator in a generator system is to maintain a constant output voltage under varying load conditions. Of the many factors that determine the output voltage of a generator, the only one that is readily controllable is the magnetic field strength. The voltage regulator controls the output of the generator by controlling the current through the field coils and, consequently, the strength of the field. Although there are many ways in which this can be done, one method is to use a carbon-pile type of voltage regulator to control the current in the field coils.

Operating characteristics. As you know, carbon is a conductor of electricity. It is far from being a perfect conductor, but it has several electrical characteristics that warrant its use. First, the more mechanical pressure (compression) applied to a number of carbon units in contact with each other, the less is the resistance of the group. As carbon units are compressed, their resistance decreases; and conversely, as the mechanical pressure exerted upon the assembly is relieved, their resistance increases. The carbon particles are always in contact with one another, with the resistance-determining factor being the amount of compressive force exerted upon them. The second all-important characteristic is that the effect of increased temperature upon carbon is the exact opposite from the reaction of the other types of conductors previously discussed in this course. As the temperature of copper, silver, and aluminum increases, the resistance of these metals goes up also. But, with carbon, as the temperature increases, the resistance decreases.

The carbon-pile regulators presently used in aircraft are manufactured by many companies and may vary slightly in external appearance; but mechanically and electrically, they operate alike. A detailed construction and wiring diagram is shown in figure 3-8. (NOTE: Callout letters of components are shown in parentheses, while base connections are identified without parentheses.) In this type of regulator, carbon discs (a) are placed in an insulating ceramic tube (b) inside of the carbon-pile housing (c). The housing is fitted with fins to radiate the heat produced as the current flows through the resistance of a voltage coil (h). An adjustable core (k) is located within the solenoid housing (g) at one end of the carbon stack. An insulated plate and adjustable screw (p), which makes contact with the carbon pile, is mounted on the other end of the carbon-pile housing. The other contact with the carbon pile is made through the armature assembly (d). When the generator is producing a voltage below that to which the regulator has been adjusted to maintain, the spring (l) exerts a

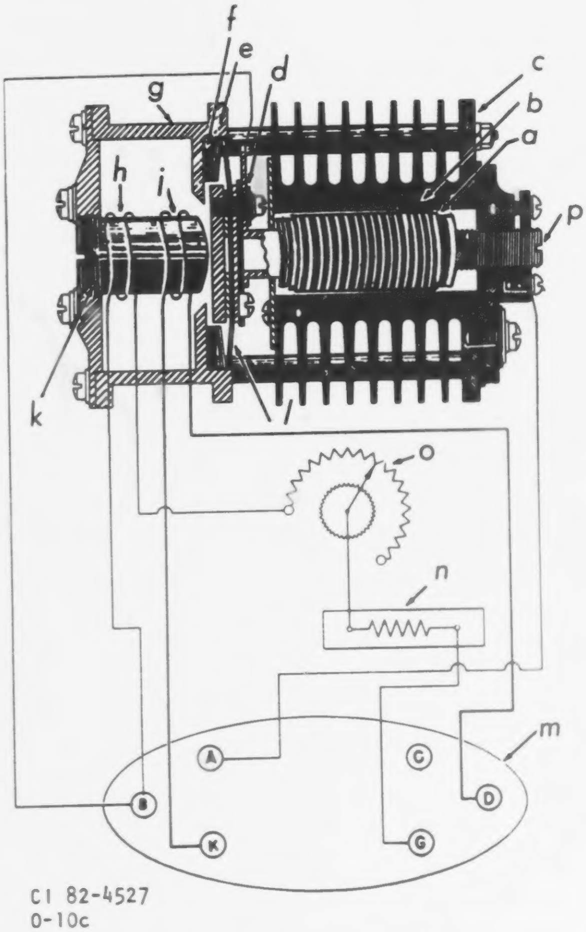


Figure 3-8. Carbon-pile voltage regulator.

mechanical pressure upon the discs, decreasing the stack resistance. This allows more current to flow through the field coils. A spacer (f) is located under the spring. This spacer is installed by the manufacturer or overhaul activity so as to place the armature in the proper position. Because the resistance of the carbon stack varies inversely with the temperature to prevent any change in surrounding air temperature from affecting the setting of the regulator, a bimetallic compensating ring (e) is situated on top of the spacer and under the tip of spring (l) which exerts the mechanical pressure on the carbon stack. As the temperature of the surrounding air increases, the compensating ring tends to flatten out and by so doing, decreases the mechanical pressure exerted upon the stack. The resulting decrease in mechanical pressure on the carbon stack increases the resistance of the stack sufficiently to compensate for the decrease in resistance resulting from the increased surrounding air temperature.

The electrical circuits of the regulator are all brought out from the base plate (m) through which the circuits are automatically completed when the regulator is installed in the standard Air Force voltage regulator base. Changes in the voltage of the generator are applied to the voltage coil (h) through terminal B of the base plate and to the variable resistor, the fixed resistor, and to ground through terminal G of the base plate. The electromagnet works in opposition to the spring that tends to compress the carbon stack. Therefore, as the voltage of the circuit increases, the current flow through the voltage coil increases and exerts more attraction for the armature. Any movement of the armature, however slight, toward the core of the electromagnet tends to increase the resistance of the stack of carbon discs. The field current of the generator has to flow through the carbon stack from one end to the other; thus current flow through the field coils is controlled by the output voltage of the generator.

The fixed resistor (n) in the electromagnetic circuit is for the purpose of limiting the current flow in the control circuit to a low value, while the variable resistance (o) provides a means of varying the resistance in the control circuit, and in this manner determines the voltage which the regulator will maintain.

A glance at figure 3-8 shows that there is one more coil in the electrical circuit which hasn't been mentioned before, and that is the equalizer coil (i), which is connected between terminals D and K of the base plate. The equalizer circuit is wired into the circuit only in installations where two or more generators are being operated in parallel to supply the electrical load. We will discuss the equalizer circuit later in this chapter.

The only adjustment authorized on a voltage regulator outside of depot activities or maintenance shops is the variable resistor. Turning this adjustment from one end of its travel to the other should provide a voltage range of from 26 to 30 volts when the generator is operating within its normal speed range and the regulator is performing normally. Any time that the voltage regulator does not automatically control the voltage within ± 0.25 volts of its setting throughout the full-load capacity of the generator, the carbon discs are wearing or the regulator is internally out of adjustment.

Many voltage regulators replace the variable rheostat with a potentiometer, which is used as both a control and protective circuit. Figure 3-9 shows a schematic of a carbon-pile regulator with a potentiometer. Note that a stabilizing resistor, c, has been added. If the moving contact burns off or is otherwise damaged, current continues to flow in the voltage coil circuit, but now it must flow through the full resistance of the potentiometer. Because of the added resistance in the control circuit, the output voltage is higher than normal. However, current is flowing in the voltage coil circuit, preventing the carbon stack from going to a minimum resistance condition. This prevents the output voltage from reaching its maximum value, reducing the possibility of damage to the generator or of having an electrical fire.

The purpose of the stabilizing resistor circuit is to prevent the arcing that formerly occurred between the discs of the carbon pile. If all the load is removed suddenly, the voltage output of the generator rises above normal for a brief instant. This high voltage being impressed upon the voltage control circuits causes a higher-than-normal current flow through the voltage coil. The resultant movement of the armature assembly of the regulator is abrupt and may cause the discs to separate completely. When this occurs, the magnetic field surrounding the field coils collapses and induces a voltage in the coils (self-induction). This voltage tends to continue the flow of current in the same direction and to produce an arc between the discs. By having the stabilizing resistor in the circuit, another path is provided for this current in the event that the discs separate; thus the arcing tendency is eliminated. This improvement greatly reduces damage to the carbon pile and lengthens the service life of the regulator.

Inspection. Normal operation of the voltage regulator is accompanied by the radiation of large amounts of heat from the regulator to the surrounding air. You must take care to insure that no item of your clothing or other material is placed over the voltage regulator. This would restrict the free circulation of air over the regulator and cause the operating temperature of the carbon pile to increase. Previously, it was mentioned that as the temperature of the carbon increases, its physical resistance is decreased. For this reason, if free circulation of air about the voltage regulator is restricted, the voltage of the system tends to rise above its normal level.

While you are inspecting voltage regulators, always look under the regulator mounting base and remove any loose nuts, bolts, or scraps of wire that might be found there. Then, check the shock mounts by which the regulator mounting base is fastened to the aircraft structure for any evidence of damage. If it is necessary for you to remove the regulator from the base, make certain the generator is not running at the time; otherwise, dangerous arcing occurs or the contracts on the voltage regulator base become damaged. When you are checking the operation of the voltage regulator, you must use a precision voltmeter. Allow the regulator to operate for a least 15 minutes so that it reaches the proper operating temperature.

When you are checking and adjusting the voltage regulator, the positive lead of the precision voltmeter is connected to B terminal of the voltage regulator mounting

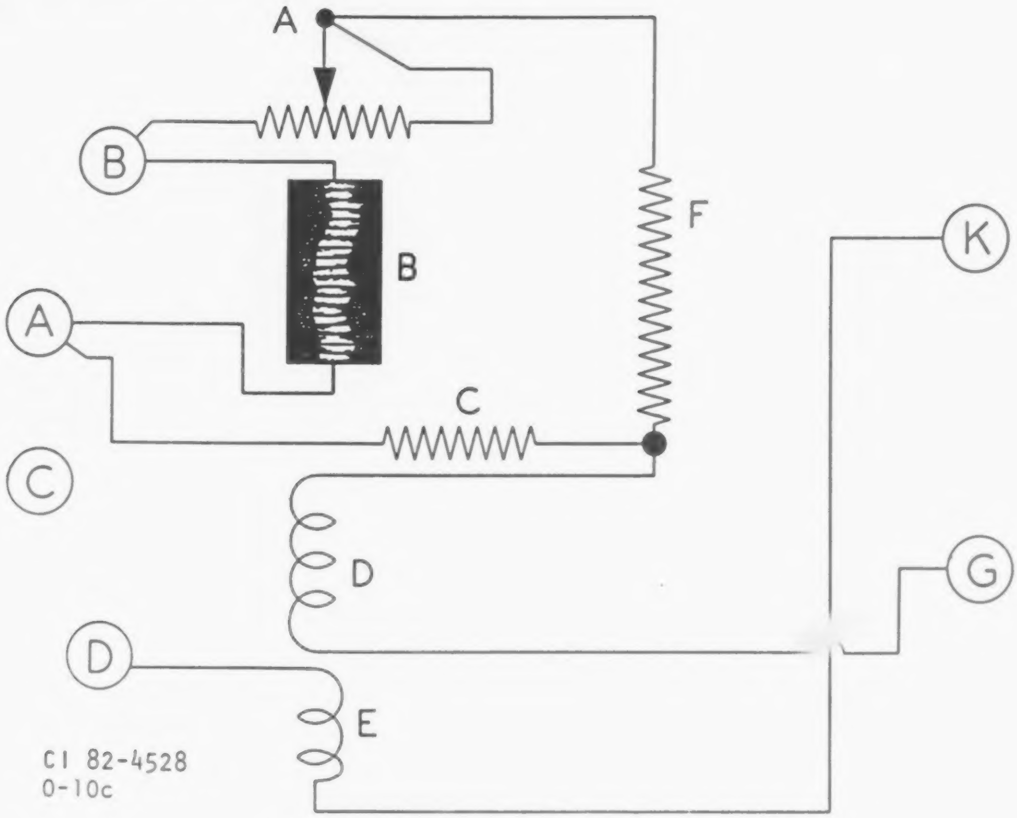


Figure 3–9. Voltage regulator with stabilizing resistor.

base (with the voltage regulator mounted) and the negative lead to ground. When the regulator warmup period is completed and the engine is operating at a speed established by the applicable TO, the voltmeter should read 28 volts and should maintain that reading as an electrical load is applied and removed from the generator. There should be only slight surges in voltage when large electrical loads are applied to or removed from the generator.

Exercises (230):

1. List three items or areas that should be checked when inspecting around a DC generator carbon-pile voltage regulator.

2. What happens to current flow through the field coils if carbon stack resistance is lowered?

3. What is the effective range for which the carbon-pile voltage regulators can be adjusted?

4. What is the purpose of the stabilizing resistor circuit?

5. Why must a regulator be allowed to warm up before it is adjusted?

6. Explain what occurs if free circulation of air around a carbon-pile voltage regulator is restricted.

231. Cite the purpose and the operating characteristics of the reverse current relay, overvoltage relay, and field control relay.

Reverse-Current Relays. These relays are generally referred to as a differential voltage reverse-current relays. They serve the following four main functions: (1) to close the circuit between the generator and the power distribution system when the generator voltage is greater than the bus voltage, (2) to open the circuit between the generator and the distribution system whenever the bus voltage exceeds the generator voltage; (3) to keep the circuit open between the generator and the power system in the event of reversed polarity of the generator; and (4) to act as a remotely controlled switch. It is referred to as a differential relay because it operates on the difference between generator and bus voltage, rather than a fixed relay that operates only when the generator voltage reaches a specific value. The basic unit is composed of three relays inside of one case, the wiring of which is shown schematically in figure 3-10. The relays are designated as follows: voltage relay, differential relay, and main contactor relay.

For the RCR to close the circuit from the generator to the bus, the generator switch must be in the closed position. (Refer to fig. 3-10.) When the generator potential reaches a point between 20 and 24 volts and, depending on the state of charge of the battery, the current flowing through the voltage relay coil (k) creates a magnetic field that causes the voltage relay contacts (j) to close. This voltage must be of the correct polarity, or the permanent magnet armature will not operate. With the closing of the voltage relay contacts, a circuit is completed from the GEN terminal to the BAT terminal by way of the differential coil (l). This is not the main current path through the relay. With a potential on the GEN terminal that is between 0.35 and 0.65 volt higher than that at the BAT terminal, enough current flows through the differential coil to displace the permanent magnet armature and close the differential relay contacts (c). The contactor coil is, in this manner, now connected to the SW terminal, from which point the circuit is completed back to the voltage source (the generator). The generator voltage applied at the SW terminal causes the main contactor coil to operate the movable core, closing the main contactor points. This completes the load-carrying circuit.

The main contactor points complete a circuit between the BAT and GEN terminals. When the generator potential drops to a value lower than the battery voltage, current flows from the battery to the generator, rapidly draining the battery. When the flow of reverse current reaches a predetermined point between 16 and 25 amperes, it overpowers the magnetic effect of the differential coil and reverses the polarity of the differential relay electromagnet. This reversal of polarity causes the differential relay contacts to open and, thus, opens the contactor coil circuit. The spring-loaded main contactor points then open and interrupt the reverse flow of current through the generator.

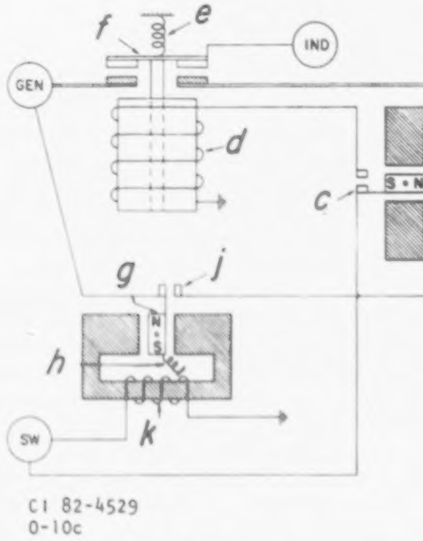


Figure 3-10. Reverse current relay.

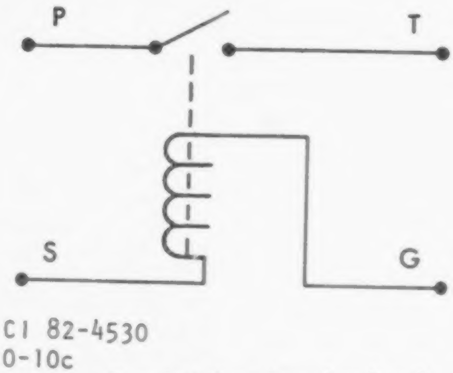


Figure 3-11. Overvoltage relay schematic.

When performing an inspection, always check the relay's mounts for damage, check for corrosion and security of electrical connections, and insure that connecting wires and cables are in good condition.

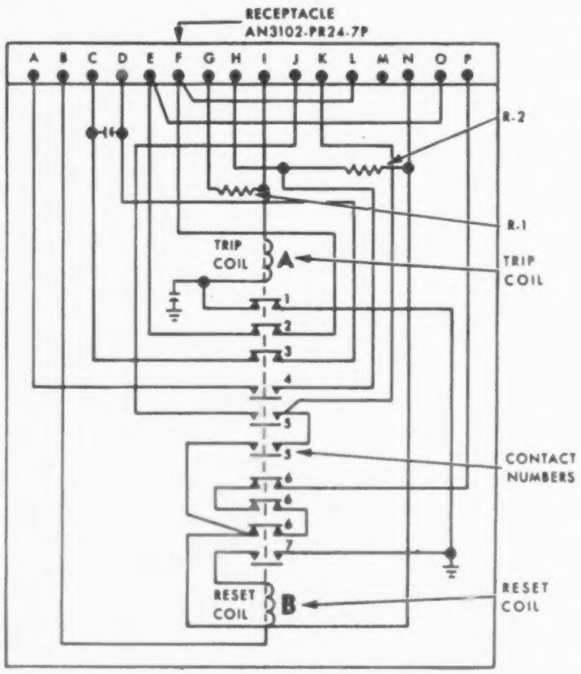
Overvoltage Relay. In any generator system, there is always the possibility of excessive voltages due to certain circuit malfunctions. If this should occur, the overvoltage condition is sensed by the overvoltage relay, which sends a trip signal to the field control relay. The field control relay then isolates the faulty generator.

A typical schematic diagram of the overvoltage relay is shown in figure 3-11. Sensing power is applied to terminal S of the relay. If the generator output voltage exceeds a certain value, the sensing power is strong enough to energize the relay through the ground at terminal G. When the relay coil is energized, a circuit is completed through contacts P and T. Terminal P is connected to the aircraft positive bus, and terminal T is connected to the trip coil of the field control relay. Completing the circuit from P to T effectively disconnects the generator from the distribution system when overvoltage conditions occur.

When performing an inspection, check the relay's mounts for damage, check for corrosion and security of electrical connections, and ensure that connecting wires and cables are in good condition.

Field Control Relay. The overvoltage relay just discussed protects all electrically operated equipment from damage caused by excessively high voltages. A field control relay is used to protect the generator and its associated wiring. A schematic of a typical field control relay is shown in figure 3-12. There are 2 relays inside the housing, the trip relay (A) and the reset relay (B), and 10 sets of electrical contacts, 6 of which are normally closed and the remaining four normally open when the generator system is operating normally. The relays used in this unit are latch-type units, meaning that once a relay is energized and the contacts moved to a certain position, the contacts are mechanically held in that new position until the other relay coil is energized.

The two relays actually work against each other, the trip relay moving the normally closed contacts to an OPEN position and the normally open contacts to the CLOSED



RELAYS SHOWN IN RESET POSITION

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Figure 3-12. Field control relay schematic.

position, while the reset relay reverses the contact positions again. The resistor R-1 is connected into the circuit to prevent damage to the trip coil that might otherwise be caused by an overvoltage condition; therefore, the resistor is connected in series with the trip coil. The second resistor, R-2, is connected between terminal H, which is connected directly to the bus bar, and terminal N, which is connected to the shunt field terminal of the generator. This resistor is installed for the express purpose of keeping a positive voltage applied to the field terminal of the generator at all times. The ground circuit of each of the two relays is completed across contacts 1 and 7, which open after the corresponding relay has been actuated. Since the contacts are mechanically latched into position after the operation of a relay, there is no need to continue to energize the relay coil; consequently, these contacts are provided to open the circuit after the relays are actuated.

The field circuit between A terminal of the voltage regulator and A terminal of the generator is completed through three sets of contacts (6) that are connected in series. The principal reason for having three sets of contacts in series is to make sure that the circuit will open. The warning light is wired through the normally open contact (4). When the generator system is operating normally, the light is out because this circuit is open; but any time that the field control relay has been actuated, the light comes on to tell the pilot or engineer that the generator is not performing normally. The wire that runs between the pilot's or engineer's control switch and the SW terminal of the reverse-current relay is controlled by a set of normally closed contacts (3) so that the reverse-current relay is also automatically disconnected in the event of circuit troubles.

Another circuit that may also be wired through the field control relay is the equalizer circuit in those installations where two or more generators are operating in parallel to supply the electrical load.

When inspecting the FCR, check the relay's mounts for damage, check for corrosion and security of electrical connections, and ensure that connecting wires and cables are in good condition.

Exercises (231):

1. When does the RCR, known as a differential voltage-current relay, close the circuit between the generator and the power distribution system?

2. Whenever the bus voltage exceeds the generator voltage, what does the differential voltage-current relay do?

3. If there is excessive voltage due to certain circuit malfunctions, the overvoltage relay does what?

4. The field control relay recieves an indication of excessive voltage from what unit or component?

5. What does the field control relay do when an overvoltage condition exists?

6. During inspection of an RCR relay, an overvoltage relay, or a field control relay, what checks should be performed?

3-3. DC System Operation

So far you have learned about the various types of DC generators used in aircraft electrical systems. You have also learned the purpose of the control and protective devices used in DC generator systems. Now we will discuss how all these components fit together to form a complete operating system.

You must know how a system operates under normal conditions before you can troubleshoot that system. It is not enough to know that a generator system contains certain components. You must know how these components are interrelated and what effect they have on each other.

Another factor you should consider is that many aircraft have more than one generator in the DC system. When you are required to perform maintenance on these systems, you must know the requirements for paralleling, as well as the actual paralleling procedure.

A generator control system provides both control and protection for the DC generator throughout its operating range, from no-load to full-load. With this in mind, let's start by discussing a single-generator system and see how control and protection are provided.

232. Cite how a single DC generator system functions.

Single Generator System Operation. The single generator control system regulates, controls, and protects the generator. You may find the essential units—reverse-current relay, field control relay, overvoltage relay, and the voltage regulator—at various locations on the aircraft or as parts of an elaborate control system contained in a single box mounted on an assembly rack and called a generator-control panel. Both systems provide the control and protection necessary for aircraft operation.

Figure 3-13 shows a typical single-generator control system with all the necessary control system components. The system also contains an ammeter, a generator failure light, and a voltmeter, all of which provide the crew with a means of monitoring the system.

The voltmeter is shown connected to one side of the generator switch, then to the voltage regulator, and then to the reverse current relay. However, in some installations it may be connected directly to the GEN terminal of the reverse-current relay. This voltmeter is a general reference instrument and should never be used when making adjustments of the system voltage. The generator switch provides the pilot with manual control over the generator system.

For the generator system shown in figure 3-13, when the battery switch is closed (ON position), 24 volts DC from the bus will be applied to terminal H on the FCR, to P on the OVR relay, and to terminal 2 on the generator switch. The necessary initial power is now applied to the generator control system. The purpose of this initial power is to provide trip power in the event of an overvoltage condition and to apply a positive DC potential to the generator field.

As the engine starts and the generator comes up to speed, generator output is applied to the GEN terminal of the RCR. The generator output could be residual or its rated output, 28 volts DC. If the field circuit is complete (FCR closed) and the generator switch is on, the generator output is 28 volts DC, and the generator is automatically connected to the aircraft bus through the reverse-current relay (RCR).

After the generator is connected to the bus, suppose its output voltage should drop below battery voltage; current would then flow from the battery to the generator. This reverse current could damage the generator windings. Under these conditions, the generator would be removed from the bus. This reversal of polarity causes the differential relay contacts to open and thus open the contactor coil circuit. The spring-loaded main contactor points would then open and interrupt the reverse flow of current through the generator.

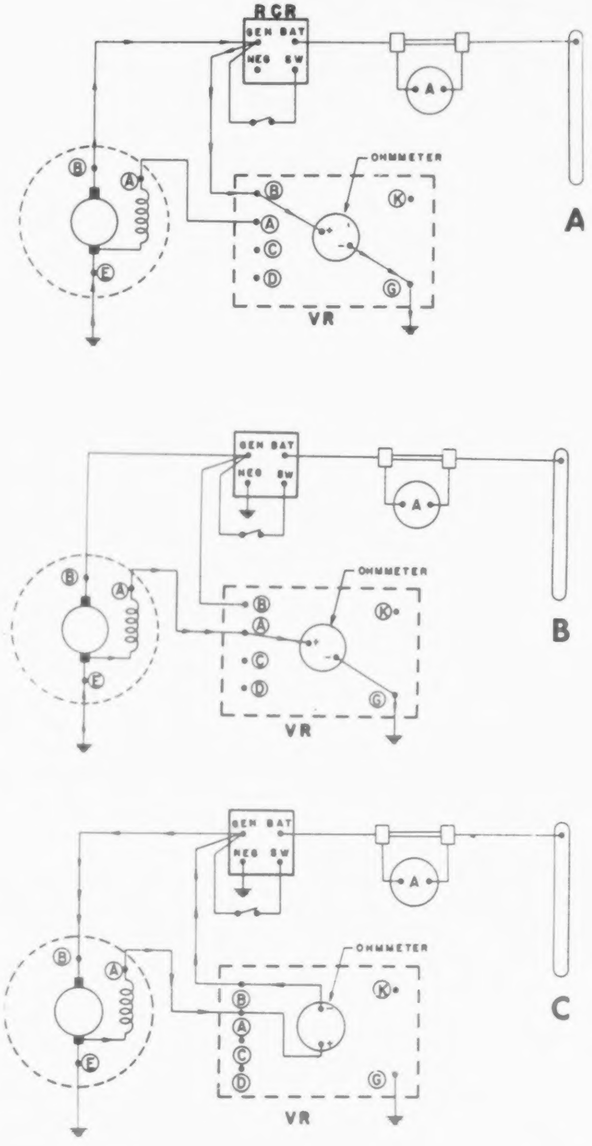

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Figure 3–13. Single generator system.

Generator output voltage is maintained constantly throughout its operating range by the voltage regulator (VR). Figure 3-13 shows how the field circuit is powered from the GEN terminal of the RCR to the voltage regulator (VR) through the carbon stack, then on through the field control relay to the A terminal on the generator. The current flow in the field circuit is controlled by the carbon stack. Any change in speed or load will affect the carbon stack resistance and, in turn, the generator output voltage.

The generator field circuit is routed through the FCR between terminals P and N. Any time an overvoltage condition exists, the overvoltage relay will trip the FCR and open the field and switch circuits. This will cause the generator voltage to drop to residual, and the RCR will remove the generator from the aircraft bus. The FCR will also cause the generator failure light to glow. The FCR can be reset by the generator switch or manually by pushing the reset button on the relay itself.

The OVR senses the generator output voltage. Figure 3-13 shows the sensing circuit connected from S terminal on the OVR through the ON position of the GEN switch, to the B terminal of the voltage regulator (VR). Thus, you find that the OVR is always connected to the output of the generator. If the generator output voltage increases to a predetermined value (approximately 32.5 volts) due to some circuit fault, the contacts between P and T of the OVR close. When these contacts close, power from the aircraft bus is applied to G on the FCR and the field control relay trips. The generator is removed from the aircraft bus in the same manner as previously described.

This completes the discussion on the operation of the single-generator system. You should be familiar enough with the circuitry of the single-generator system to troubleshoot it. However, this will be covered later on in this chapter.

To be sure that you know and understand the single-generator control system, trace the operation of each component once more on figure 3-13.

Exercises (232):

1. What three components (on the single generator system) provide the crew a good means for monitoring the system?

2. The voltmeter is directly connected to what three components?

3. a. Initial power comes from what component?

   b. This initial power is applied to which three components?

4. What is the purpose of initial power on the generator system?

5. What controls the current flow in the field circuit?

6. How may the field control relay be reset?

7. What approximate voltage will cause the overvoltage relay to close?

233. Cite operating characteristics of a DC multi-generator system.

Multi-Generator System Operation. This system performs the same functions as the single-engine control system. Except for one feature, it is a duplication of the single-generator system. Each multi-generator system has an equalizer circuit. This circuit parallels the generators and insures that each generator will carry its share of the load. This is called equalizing the amperage output of each generator in relation to the current output of the other generators connected to the power bus when a DC load is applied.

When two or more generators are operated at the same time to furnish current, it is necessary that each generator furnish an equal share of the total load. As long as all the generators are operating, there is no sense in having one doing all the work and the others loafing on the job; then, too, by distributing the load equally, the wear is divided among the generators.

When two generators, as shown in figure 3-14, are supplying equal amounts of current to the load, the currents through the equalizing resistors (J) are equal and the voltage drop across both equalizing resistors is the same; therefore, the potential at both generator D terminals (inside circular dotted lines) is the same. This represents the ideal operating condition. (NOTE: Component terminals are shown in parenthesis, while generator terminals are listed without the parenthesis.) When the current outputs from the generators become unequal, a difference in potential exists at the D terminals. Remember that a current flows in the equalizer circuit any time there is a difference in potential and a complete electrical circuit exists between points D and D. This small difference in voltage is responsible for the operation of the equalizer circuit.

All voltage regulators have an equalizer coil wound around the magnetic core of the voltage coil. The equalizer coil consists of a comparatively few turns of small wire, the ends of which are connected to the (D) and (K) terminals of the regulator sub-base, as shown in figure 3-14. Since current may flow through the equalizer coil (F) in either direction, the polarity produced by the equalizer coil depends on the direction of current flow. When coil current flow opposes the polarity produced by current flow through voltage coil (H), it reduces the magnetic strength of the voltage coil core. This reduction in the effective magnetic strength of the coil core allows the spring to compress the carbon pile (located between terminals (A) and (B) on the schematic), with the result that more current flows through the shunt field of the generator and causes the generator

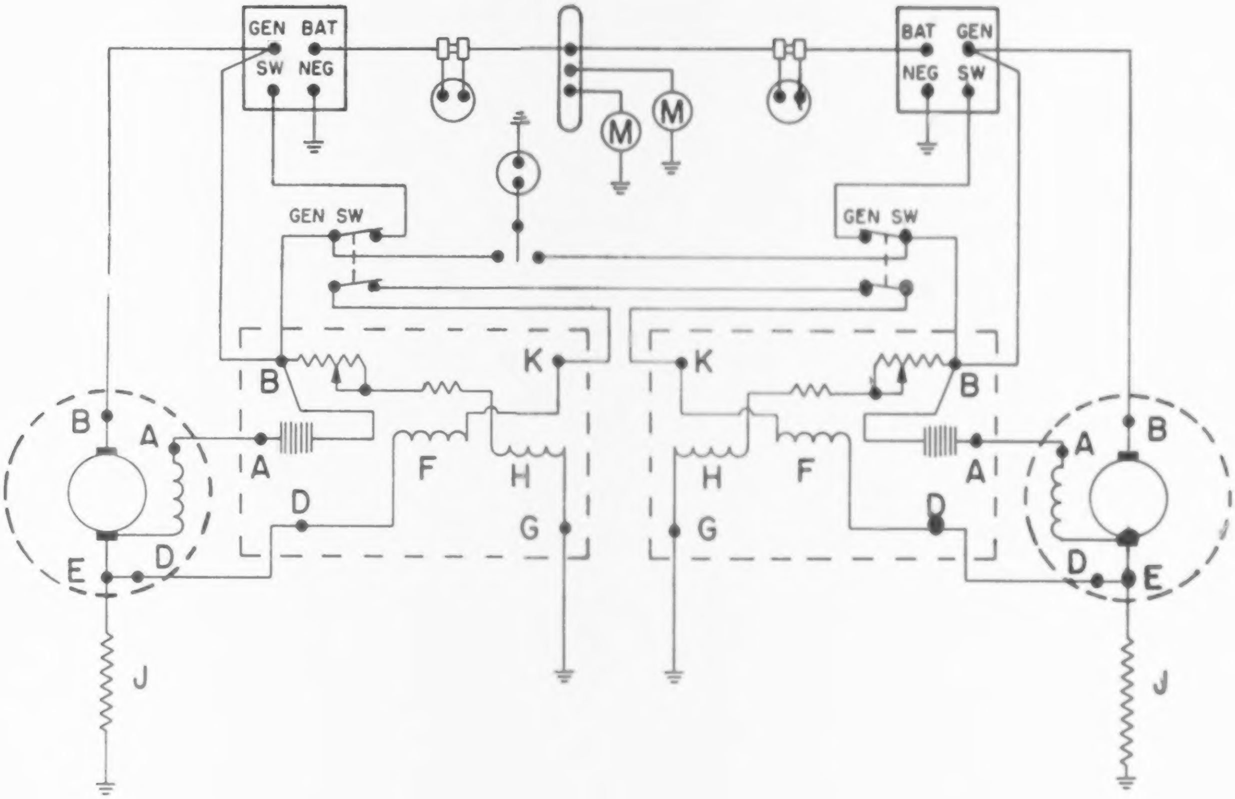

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Figure 3-14. Multi-generator equalizer circuit.

voltage to increase. Conversely, when the current flows through the equalizer coils (F) so that its magnetic polarity is the same as that of the voltage coils (H), the magnetic core of the voltage coil is increased. The added strength of the magnetic core decreases the spring pressure on the carbon pile and thereby decreases the field current and, consequently, the generator output voltage. Thus, we find that the direction of the current flow in the equalizer coil (F) determines whether the voltage of its generator will increase or decrease, and we should also understand that the amount of current flowing in the equalizer circuit governs the amount of change that occurs in the generator voltage output. Since the equalizer normally can raise or lower the voltage of a generator only 0.3 volt, the voltage regulators first must be used to adjust the voltage outputs of their respective generators as closely as possible to enable the equalizer coils to maintain parallel operation.

If one generator of a paralleled system becomes inoperative, there is no current flow through its equalizing resistor (J); consequently, the voltage at the D terminal of that generator would be the same as if it were not sharing the load distribution. The current flow in the equalizer circuit would be such as to reduce the voltage of the operative generator by as much as 2 or 3 volts when large electrical loads are applied. To prevent this highly undesirable condition, the equalizer circuit of the faulty generator must be interrupted. This has been accomplished in some installations by physically removing the regulator of the inoperative generator system from its base. Some installations pass the (K) lead through one side of a double pole switch, as shown in figure 3-14, the other side of which controls the operation of the corresponding reverse-current relay. Opening the generator switch then automatically opens the (K) lead and prevents the drop of bus voltage when the generator becomes inoperative. In systems that incorporate the field control relay, the equalizer circuit is completed through a set of normally closed contacts that open in the event of an overvoltage condition. If an overvoltage condition occurs in a system not having this protective equipment, a current would flow through the equalizer circuit in such a manner as to reduce the voltage of the high-current generator(s). If the field control relay is actuated by an overvoltage condition, the equalizer circuit for that generator is automatically opened, and so it does not have any adverse effect on the operation of the remaining generators. Now we are ready to cover paralleling procedures. After you have made the voltage regulator adjustments, increase the speed of all engines to their normal crusing range and close all generator switches. Next, apply an electrical load, such as lighting equipment, inverters, and radio equipment, equivalent to approximately the full-load rating of one generator. In some aircraft, the ratio of generator capacity to normal aircraft load is so great that it may be difficult to turn on enough equipment to obtain the above specified loads. In those instances, turn on as much equipment as possible. Next, observe ammeter readings. The difference between the highest and lowest generator currents should not exceed TO specifications. If the generators are not dividing the load properly, first lower the voltage of the generator providing the greatest amount of current, and then slightly raise the voltage of the lowest current-producing generator by adjusting the corresponding voltage regulators. Exercise care not to change the voltage to any great extent. After you have made all voltage adjustments, make a final check of the bus voltage by connecting the precision voltmeter from the positive bus to ground. The voltmeter should read 28 ± 0.25 volts. If the bus voltage is not within these limits, readjust all voltage regulators individually for 28 volts at NO LOAD and then repeat the paralleling process.

In some aircraft installations, remote control of the voltage regulators is required. This means that the rheostat must be electrically separated from the voltage regulator. To keep all voltage regulators interchangeable, the voltage-adjusting rheostat is not physically removed or disconnected; instead, remote control is accomplished by turning the rheostat on the regulator assembly to its minimum resistance position and inserting another variable resistance in series with it. The remotely located rheostat may then be positioned in any convenient location. The primary purpose of this remote control arrangement is to provide a voltage adjustment near the ammeters to facilitate the paralleling of the generators on aircraft using two or more generators. The rheostat on the voltage regulator assembly must not be used for making the voltage adjustments in installations with remote control rheostats.

In the past few years, it has been the tendency to bring all of the individual circuit-controlling devices into one common unit. This unit is now called a *generator control panel*. The entire control panel is mounted so that it may be replaced very easily in the event of failure or malfunction of any one of its components. A generator control panel is a device associated with the newer generator installations. The purpose of the panel is to provide a compact installation that includes most of the various relays and voltage regulators. Obviously, such a compact arrangement facilitates easier testing, troubleshooting, servicing, removal, and installation of these components.

Exercises (233):

Refer to figure 3-14 to answer the following exercises:

1. a. What circuit is responsible for parallel operation of the DC generators?

   b. When does it operate?

2. What terminals on the voltage regulator does the equalizer circuit utilize?

3. After paralleling the generators, you check the ammeters and the load is not being properly divided. What do you do?

234. Select the probable cause of malfunctions in a DC generator system.

Troubleshooting. Aircraft must be kept at their highest efficiency at all times. Since most combat equipment is electrically operated, the power system must be kept in perfect operating condition. In addition to the combat equipment, the flight controls, radio, lights, guns, and many other devices are also dependent upon the electrical system.

Troubles may develop at any time in a properly maintained generator system, but they are more likely to occur when operating the aircraft under the tremendous loads of combat conditions. In order to keep the system at its highest peak of efficiency, it is essential that the electrical repairman be able to recognize, diagnose, and eliminate troubles from the system at the earliest possible moment. In order to maintain and troubleshoot the generator system, you, the aircraft electrical specialist, must intelligently apply your technical knowledge to each unit in the system.

Refer to figure 3-14. Troubleshooting starts with the cockpit voltmeter and ammeter, because these instruments are wired into the circuit; thus they give the pilot or engineer a continuous check on the output of each of the installed generators. A normal voltmeter reading is 28 volts and any deviation from this figure indicates that a fault exists somewhere in the system. A voltage indication that is only slightly higher or lower than the normal voltage could mean that the voltage regulator needs adjustment. Four types of voltage readings which indicate serious trouble are: (1) a reverse voltage reading, (2) a residual voltage reading, (3) a zero voltage reading, or (4) an excessive voltage reading.

Before an intelligent diagnosis can be made, you must know what the desirable voltage output of the generator is under normal conditions, as well as the various causes of abnormal voltage readings. Since abnormal voltmeter readings tend to show the location of the troubles in particular parts of the circuit, you will find it helpful to learn the following generalized causes of certain abnormal voltages. If the cockpit voltmeter shows an abnormal voltage, the first thing to do is to connect a precision voltmeter into the circuit between (B) terminal of the voltage regulator base and ground (reference fig. 3-14). This ensures that the cockpit voltmeter is giving a true indication of the operation of the system.

Reverse voltage readings. This type of voltmeter reading shows that the generator voltage output is reversed or that the voltmeter is connected incorrectly. A quick check with another voltmeter connected between B terminal of the voltage regulator base and ground will show whether the voltmeter or the generator is at fault. If the voltmeter has been replaced recently, there is a strong likelihood that the leads to the new instrument were placed on the wrong terminals. If the generator has just been replaced with a new unit, it is possible that the B and E leads on the generator have been reversed. If neither of the units has been replaced recently, the only possibility remaining is that the generator polarity has been reversed.

You can correct reversed generator polarity by flashing the field. You accomplish this by momentarily connecting a small-diameter wire between the A terminal of the voltage regulator base, with the regulator assembly removed, and a positive source of voltage (BAT) (fig. 3-15) while the engine is running at an idling speed. This passes a current through the shunt field coils in such a direction as to restore the magnetism to its correct polarity. If the cockpit voltmeter is visible during this process, you should note a voltage reading during the field-flashing process because the armature rotates in the magnetic field produced by this current flow. The voltage reading should decrease to a residual value as the jumper wire is removed.

Residual voltage readings. When the generator is only producing a residual voltage, which ranges from 0.5 to 3 volts in value, the trouble must be in the field circuit. Since the voltage is no more than that which could be produced by the armature cutting the residual magnetism of the field pole pieces, it is only logical to assume that the trouble must be due to the lack of a current flow through the shuntfield of the generator.

Zero Voltage readings. With a cockpit voltmeter reading of zero volts, you should expect a trouble which would prevent the generator from producing voltage or which would cause the circuit to the cockpit voltmeter to be incomplete. A quick check with another voltmeter will show whether the voltmeter circuit is at fault or whether the trouble lies elsewhere.

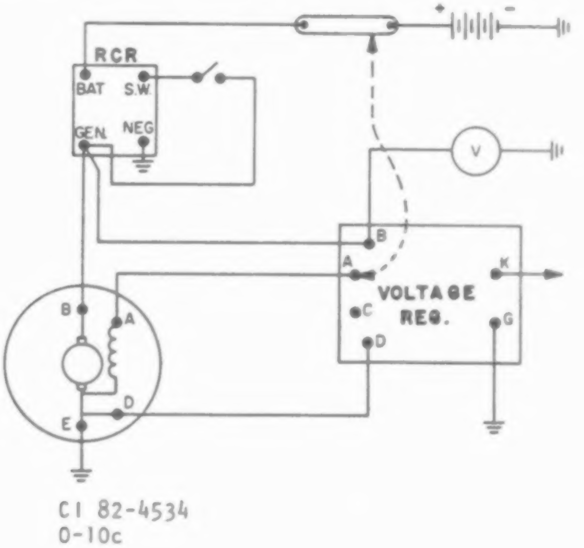


Figure 3–15. Voltmeter troubleshooting.

A zero generator voltage indication on the cockpit voltmeter can be caused by an open B lead (refer to fig. 3-15), a short between B and E, or faults within the generator, such as the loss of residual magnetism, poor commutation, or grounded positive brushes. Also, the voltmeter could be defective.

Excessive voltage readings. Excessive voltage conditions are caused by a complete lack of regulation of the current flowing through the shunt field. A short circuit between the B and A terminals at either the generator or regulator terminals could provide a low-resistance path for current to flow in parallel with the carbon stack (refer to fig. 3-14). It would allow full generator voltage to be applied to the shunt field, resulting in an excessive voltage condition. Other reasons for excessive voltage include an open in the voltage coil circuit of the voltage regulator or an open lead which connects the (G) terminal of the voltage regulator mounting base to the ground (refer to fig. 3-14).

Removal of the voltage regulator assembly from its mounting base, while the trouble exists, is one quick way of determining approximately where the trouble lies. When the voltage regulator is removed, the shunt field current should be interrupted and the voltage should normally decrease to a residual voltage value. (CAUTION: DO NOT remove or replace the voltage regulator while the system is turned ON; this action will cause arcing and damage both the regulator and its base.) If the trouble lies in the voltage regulator or the lead to ground, when the voltage regulator is removed, the system will drop to its residual value. If the trouble is a short circuit in parallel with the regulating resistance, the trouble will persist when the regulator assembly is removed and the voltage will continue to be excessive. If you know the general nature of the trouble, your next step is to locate and eliminate it from the system.

Exercises (234):

1. From what instruments does the electrician get indications of a malfunction in the electrical system?

2. Name three possible causes of reversed voltage indications.

3. How is the generator polarity changed back to the proper polarity?

4. If the generator is only producing residual voltage, what is the most probable cause?

AC Generator System

MOST OF TODAY'S aircraft use a great deal of AC power. Consequently, the primary power system used on present-day aircraft is AC. This does not mean you won't find a number of aircraft still in the Air Force that have a primary DC power system. Chapter 3 provided you with the necessary background knowledge to work on DC power systems. In fact, you will be using your knowledge of DC generators in our discussion of an AC generator in this chapter.

AC electrical loads, for the most part, require a constant frequency. But keep in mind there are AC loads that do not require a constant frequency. These loads obtain power from variable-frequency generators, also discussed in this chapter.

4-1. AC Generator

There are many types of AC generator systems in current use. However, you will be able to grasp the general idea behind all of the various types because they fall into two classifications: the variable-frequency and the constant-frequency AC generator systems. We will discuss both of these systems in this section.

235. Cite operational characteristics of the variable-frequency AC generator.

Variable-Frequency Generator. The output of the AC generator must be held to a constant value over a given range of operation. In order to do this in a constant-frequency AC system, a voltage regulator and a constant-speed drive unit must be used. In a variable-frequency system, however, only the voltage regulator is used to provide a stable output over the generator's entire speed range of operation.

AC is produced when a coil is rotated between a north and a south magnetic pole. In such a device, the strength of the generated voltage depends upon the strength of the magnetic poles, the number of turns of wire in the coil, and the speed at which the coil is rotated. The frequency of the current pulsations depends upon the speed of coil rotation and the number of poles, but not upon the strength of the magnetic field.

Let's assume that a generator rotor is connected directly to the crankshaft of an engine. With this arrangement, the rotor makes one revolution every time the crankshaft makes one. Therefore, if the engine crankshaft is turning at a rate of 1200 rpm, the rotor also turns at a rate of 1200 rpm.

Remember, don't confuse the generator speed with its frequency. Since the speed of rotation is measured in revolutions per minute (rpm) and frequency is measured in Hertz (Hz), we need to use the frequency formula to determine the output frequency of the generator.

$$\text{Frequency} = \frac{\text{number of pairs of poles} \times \text{rpm}}{60}$$

Therefore, if there is one pair of poles in the generator and it is turning at a rate of 1200 rpm, use the formula:

$$\text{Frequency} = \frac{1 \times 1200}{60}$$

Thus,

$$\text{Frequency} = 20\text{Hz}$$

It is necessary to have a gear train between the crankshaft and the rotor of the generator because the crankshaft of a reciprocating engine rotates too slowly for the desired voltage and frequency. Although a jet engine rotor turns at a faster speed than does a reciprocating engine, a gear train is still required. Since variable-frequency generators used by the Air Force generally incorporate a 12-pole field, the gear train is required to drive the rotor between 3800 and 10,000 rpm to produce the allowable frequency of 380 to 1000 Hz.

Although the frequency is allowed to vary, the voltage must be kept at a constant value. This is accomplished through the use of a voltage control circuit. A second point to keep in mind is that a variable-frequency generator can be used only in conjunction with resistance-type loads because of the varying frequency. Since capacitive and inductive reactances vary with the frequency, it is not feasible to use inductive or capacitive loads in connection with variable-frequency generators.

On the other hand, a constant-frequency AC generator can be connected to all of the various types of AC loads which include both KW and KVAR loads. This type of generator provides a constant output frequency (400 Hz) and, therefore, the rotor must be driven at a constant speed. A device known as a constant-speed drive does this task. While the drive maintains the rotor speed constant, it must also be able to vary its output (torque) to maintain the load on the generator. We will next discuss effects that various load conditions have on the generator output.

When the load on the generator is changed, the terminal voltage of the generator will vary. The amount of variation depends on the design of the generator and the power factor of the load. With an inductive load having a lagging power factor, the drop in terminal voltage when the load is increased is greater than would occur if the load had unity power factor; that is, a resistive load. With a load having a leading power factor—a capacitive load—the terminal voltage tends to rise. A change in terminal voltage with a change in generator load is due to the change in armature resistance, reactance, and reaction.

Generators of the single-phase, variable-frequency type are similar in appearance to the DC generator discussed in Chapter 3. The general appearance may vary with the manufacturer, but only slightly. However, we are interested in the internal construction and, for this explanation, we shall examine a B-1, single-phase, variable-frequency AC generator.

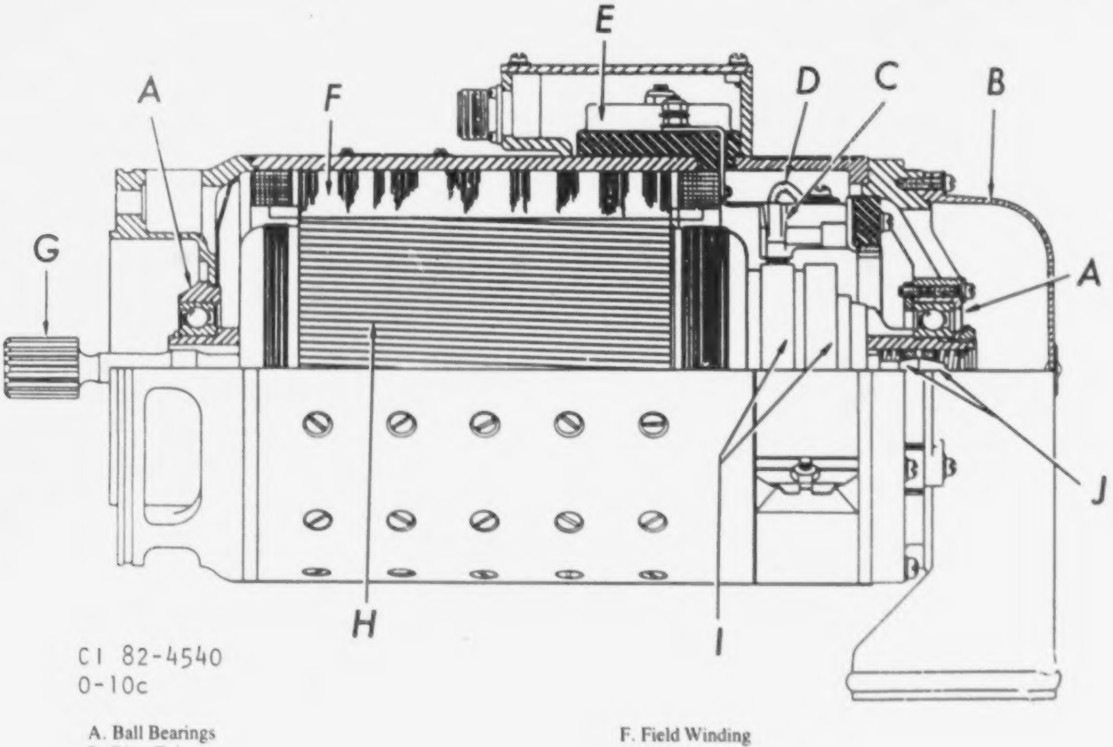
The stator (see fig. 4-1), which is the stationary set of windings (F), includes 12 laminated pole shoes whose field windings are connected in series. These shoes incorporate damper segments which form a complete "squirrel cage" winding. Such construction affords a more even distribution of the field flux. The purpose of the damper feature is to provide a better waveform in the generator output voltage by smoothing out the field current pulsations produced by the exciter regulator.

The terminal block, figure 4-1(E), is made of molded plastic and is mounted on the outside of the generator housing. The terminal block has four terminals—two for the field circuit and two for the AC output.

The rotating member of the generator is composed of the rotor windings (H), in which AC voltage is induced by rotation through the magnetic field produced by the field windings (F), and collector rings (I), which, in turn, provide a means of coupling the induced voltage to the output terminals of the generator. The rotor winding and collector rings are mounted on a shaft which is supported between ball bearings (A). A spindle (G), which mates directly to the drive unit or engine, is coupled to the shaft by means of a splined coupling along with a friction shoe damper (J). The damper provides isolation from torsional oscillations which, in turn, reduces wear and prevents spindle breakage.

A laminated asbestos phenolic ring serves as a mount for two pairs of brass brush holders (C). The carbon brushes (D) in the holders are held firmly against the collector rings by spring-loaded fingers. Cooling is provided by blast air through the blast tube (B).

Variable-frequency generators are designed to operate at a given kVA rating at speeds between 3800 to 10,000 rpm. These generators may be rotated either clockwise or counterclockwise, but the brushes must be reseated if the direction of rotation is reversed. Then, too, because of the variable frequency, these generators cannot be operated in parallel. Since collector rings are used, this type of



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A. Ball Bearings
B. Blast Tube
C. Brush Holders
D. Brush
E. Terminal Block

F. Field Winding
G. Spindle
H. Rotor Winding
I. Collector Rings
J. Friction Shoe Damper

Figure 4–1. Single-phase, variable-frequency AC generator.

generator should not be connected to heavy loads as the brushes arc and spark excessively under heavy-load currents.

Close voltage regulation is necessary for the satisfactory operation of all electrical equipment. For the single-phase type B−1 AC generator, voltage regulation is achieved with an exciter-type regulator.

Keep in mind that only a KW load (real load) is applied to the variable-frequency generator. This type of generator is connected directly to the engine; thus, the torque requirements are automatically taken care of by the engine as load is increased or decreased. Very little change in regulator output is required as long as the speed remains the same.

When engine speed is changing, regulator output must also change to maintain a constant generator output voltage. In other words, exciter-regulator output will have a greater change with respect to changing speed than it will have with respect to changing load condition, provided the load range of the generator is not exceeded.

The voltage output of the B−1 variable-frequency generator is single-phase 115 volts. Remember, there are some 3-phase, variable-frequency generators in use by the Air Force. The output voltage of these generators is the same as that of a constant-frequency, 3-phase generator which will be discussed next.

Exercises (235):

1. What is the frequency of a generator when the rotor has 6 poles and is turning at 1200 rpm?

2. a. In a constant-frequency AC system, to hold the generator's output to a constant value, what two major items are required?

   b. In a variable-frequency system, what is required to hold the generator's output to a constant value?

3. a. In order to produce the desired frequency, what unit is normally placed between the driving unit and the generator?

   b. Although frequency is allowed to vary slightly, voltage is kept very constant by means of what circuit?

   c. What type of load must we use on a variable-frequency generator?

   d. What two types of loads should not be used in conjunction with a variable-frequency generator?

4. What is the purpose of the "squirrel-cage" winding in the stator of a variable-frequency AC generator?

5. What type of load can be connected to a variable-frequency generator?

236. Differentiate between the brush-type and the brushless-type constant-frequency AC generator.

Constant-Frequency Generators. Most aircraft AC electrical equipment has been designed to operate from a constant-frequency source of AC power. Aircraft electrical equipment can be designed to operate at almost any given frequency. However, designers have established that electrical equipment used aboard aircraft operates satisfactorily at 400 Hz and also stays well within the weight restrictions imposed on the design of such equipment.

There are two different types of constant-frequency generators in general use in the Air Force today. They are the brush-type and the brushless-type, either of which may be air-cooled or oil-cooled. In this discussion, we will discuss both types of AC generators.

Brush-type. The A−1 generator is a revolving-field type of AC generator. In this generator (fig. 4-2), DC from an integral exciter generator is passed through windings on the rotor by means of sliprings and brushes. This maintains a rotating electromagnetic field of fixed polarity (similar to a rotating bar magnet). The rotating magnetic field following the rotor extends outward and cuts through the armature windings imbedded in the surrounding stator, thus inducing a voltage. Since the output power is taken from stationary windings, the output may be connected through fixed terminals directly to the external load. This is advantageous in that there are no sliding contacts, and the whole output circuit is continuously insulated, thus minimizing the danger of arc-over.

Sliprings and brushes are still used on the rotor to supply DC to the AC generator field. They are adequate for this purpose because the power level in the field circuit is much lower than in the armature circuit.

Brushless-type. The brushless AC generator is one of the new units included on later model aircraft. The change to this type of generator was considered necessary because the newer aircraft fly at such high altitudes with much larger electrical loads. Brushes are a generator's weak point at

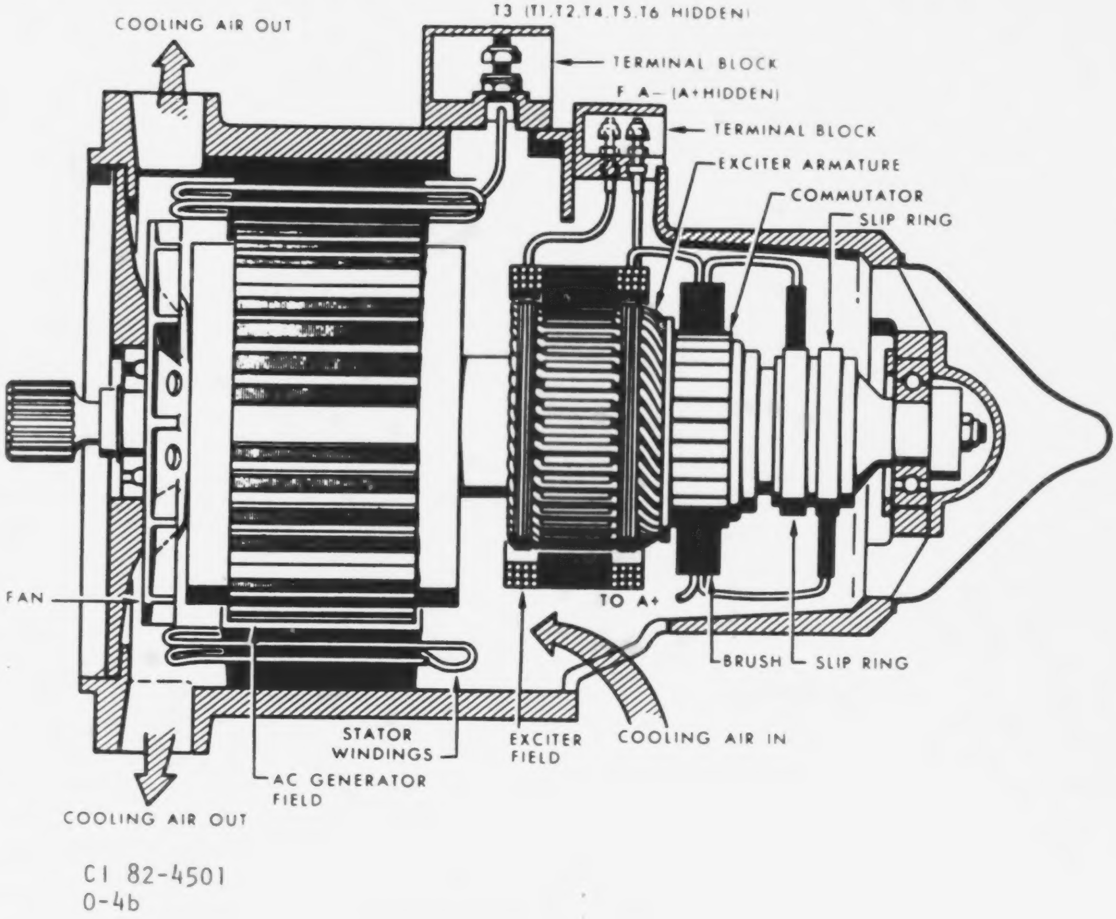

Figure 4-2. Type A-1 generator cutaway.

high altitudes due to increased arcing which more easily occurs in rarefied air. With the design of the brushless generator, however, this trouble has been eliminated.

A brushless generator is really a three-in-one unit in that the final output is the result of two previous stages or sequences. In fact, there are really three separate and distinct generators in the one unit. The first is a permanent magnet generator (PMG), the output of which energizes the field of an exciter generator through the voltage regulator. The output of the exciter generator energizes the field of the main generator. The output of the main generator is fed to and controlled by the voltage regulator by controlling the strength of the exciter output.

Let us now refer to figure 4-3 as we discuss the operation of a brushless generator. This type of generator contains a permanent magnet generator (identified as NS in fig. 4-3), which provides the initial excitation of 4800-Hz single-phase power. Current produced by the PMG is fed into the voltage regulator (not shown), which in turn is rectified and controlled by the voltage regulator, and fed back through pins F and A to the exciter stationary field. This current, exciting the exciter field, in turn produces 3-phase AC in the rotating exciter armature (shown below the exciter field). This is then fed to the 3-phase, half-wave rotating rectifiers where it is rectified to pulsating DC. This current excites the main rotating field where it sets up magnetic flux in the field poles. The rotating magnetic field, cutting conductors in the AC output windings (identified as T1 thru T6), produces a 3-phase AC output.

Inverse voltages and negative voltage spikes, which have an adverse effect on generator operation, are compensated for by including three capacitors and a diode in the generator's circuitry. The capacitors are placed in parallel with the output of the rectifier assembly and the AC generator rotating field. Their purpose is to suppress rectifier peak inverse voltage, thus preventing damage to the rectifiers upon removal of short-circuit currents or maximum-load current. A commutating diode is installed in the rear-end bell of the generator and is connected across the exciter field winding. The purpose of the diode is to eliminate or reduce the negative voltage spikes produced when the capacitor discharges after the generator control relay has been tripped, thereby preventing damage in the voltage regulator circuit due to high-transient currents.

The brushless AC generators are cooled by either blast air or engine oil under pressure. This same oil is also used to cool the rotating rectifiers, lubricate the end bearings, and cool the generator windings.

You already know that an AC voltage can be induced in a stationary coil by rotating a magnetic field in the vicinity of the coil. Also, a generator can be constructed which has the field rotating. With such an arrangement, the entire load

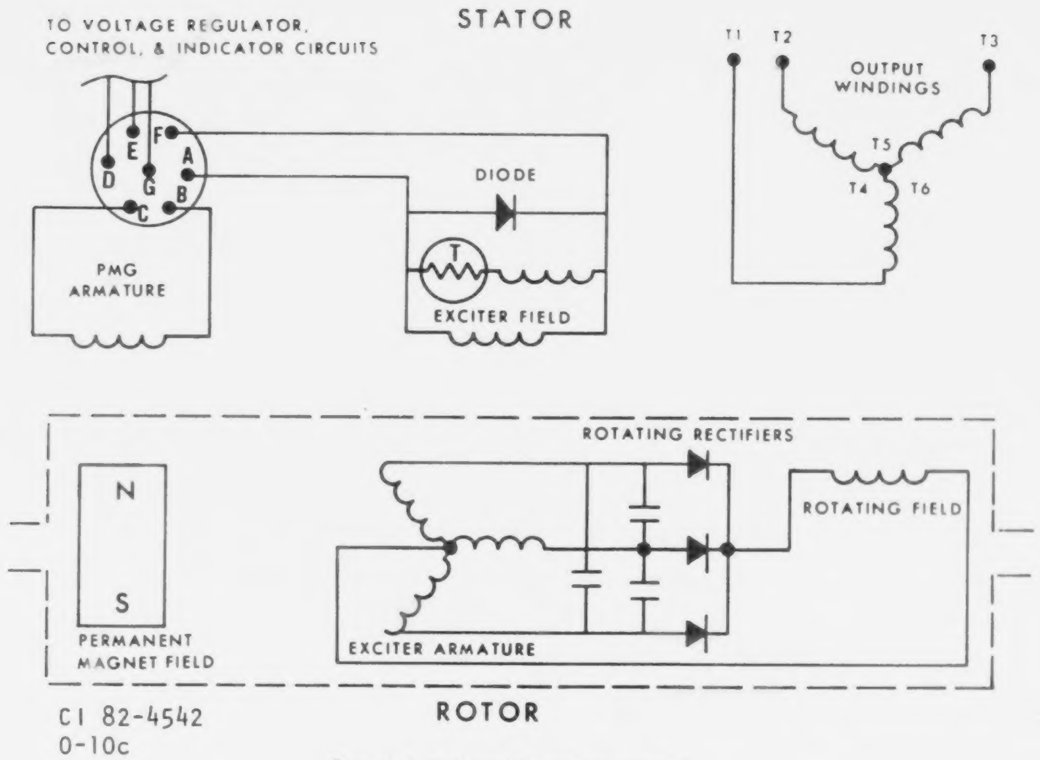

Figure 4-3. Brushless AC generator schematic.

current can be taken from the stationary winding. Consequently, the total output current does not have to be carried through the brushes. However, brushes and sliprings are still used in many generators to apply a DC voltage to the rotating field. Actually, the power required to produce a sufficiently strong field is usually less than one-tenth of the maximum output power of the generator. Therefore, this "rotating-field" type of generator is usually found where fairly large loads are desired. Then, because of the low voltage and current value in the field circuit, you seldom encounter trouble with this machine.

Let's return to the simple 2-pole generator for a moment. You will recall that one cycle of AC is produced every time north and south poles pass a coil of wire. In order to produce the required 400 Hz, a 2-pole generator would have to operate at 24,000 rpm. Aircraft engines, including jets, do not approach this speed. Therefore, some way must be devised to attain 400 Hz. This is done with an 8-pole rotor. If you check with the frequency formula, you will find that such a rotor operating at 6,000 rpm will produce 400 Hz, while some other generators have a 6-pole rotor and must operate at 8,000 rpm to produce 400 Hz. Magnetic poles on the type of AC generators we have been discussing have a shaft arrangement that gives alternate north and south poles. Each pole has a coil of wire wrapped around it, and the coils are connected in series with each other. The free leads at each end are attached to one of the two sliprings that are mounted on the rotor shaft. With this type of construction, a variable DC may be applied to the rotor winding for controlling the magnetic-field strength, which, in turn, determines the voltage output of the generator.

By wrapping three more coils, which overlap each other, around laminated iron pole shoes fastened to a circular steel housing, we form what is called the armature of the constant-frequency generator. Since these coils do not move, we refer to them as "stator windings."

These three separate coils are 120° apart. For this reason, three separate voltages are induced 120 electrical degrees apart when the rotor assembly is inserted in the stator assembly and is made to turn. Since each of the stator coils is known as a phase, the output of the stator winding is called 3-phase voltage.

There are two ends to each phase winding; therefore, six leads protrude from the stator housing. In order to complete a path for current from the generator to the load and back, we must connect these six leads in either wye, "Y," or delta, "Δ." Let's start with the commonly used arrangement "Y."

First, turn to figure 4-4. In part A of this schematic, you see the three coils of the "Y," each having two leads which extend out through the stator housing. Connecting three similar leads together forms a path for current from any one of the three coils to the other two. This forms what is commonly referred to as the *neutral* or *fourth* wire (which could be the fuselage) in a 3-phase system. Connecting a voltmeter between any one of the three open leads and this neutral, you can measure the voltage induced in each stator coil. In the 3-phase generator used by the Air Force, this voltage reading should be 120 volts AC. Since each of the stator coils is called a *phase wind*, the voltage of one coil is called *phase voltage*. Now, if the voltmeter is placed between any two of the open or phase leads, you actually

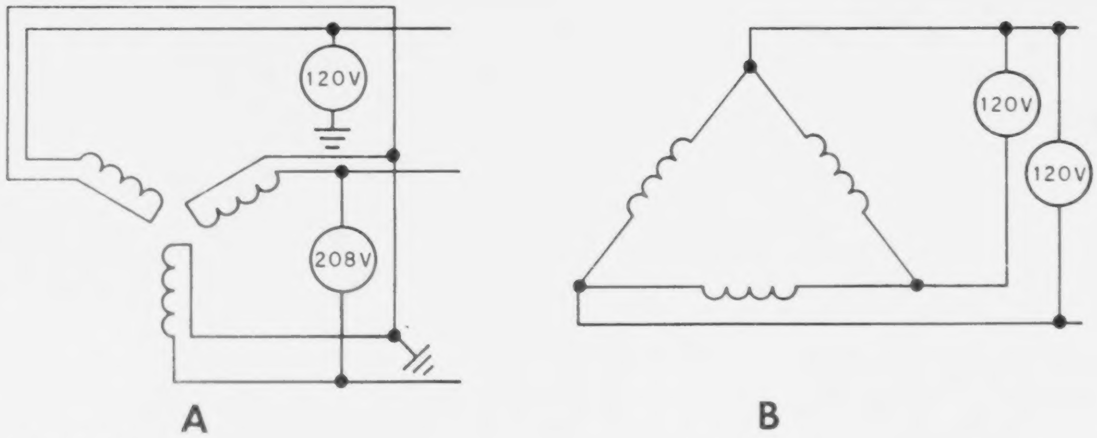

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Figure 4-4. "Wye" and "delta" connections.

obtain a line-voltage reading, which is the voltage of two of the coils instead of one. Because the coils are 120 electrical degrees apart, only one of them will be in full power at a time, while the others are at partial power. The combination of the two voltages is 1.73 times greater than the voltage of only one coil, or 208 volts AC. It should be explained at this point that the voltage in the partially powered coils is in the same direction as the voltage in the fully powered coil. Thus, both are in series, which means that the voltage of the partially powered coils is added to that of the powered. Therefore, total generator output voltage is equal to the algebraic sum of the series voltages. The major advantage of a "Y" connection is that higher phase-to-phase voltages can be obtained.

On the other hand, phase-to-phase voltage of the "Δ" connection is the same as its phase to neutral voltage because of the parallel connection of the stator coils (see fig. 4-4,B). However, it can be put to good use for it has a higher current-carrying capacity than the "Y." Now, let's check and restate the major points concerning the "Δ" system. If the stator windings and the rotor magnetic strength are the same as those of the "Y" connection and you place a voltmeter between any two of the three protruding leads, you obtain the measurement of only the voltage of one coil or 120 volts. Inasmuch as there is no neutral or fourth wire in a "Δ" system, the phase and the line voltage are the same.

The generator is driven by a constant-speed drive unit which, in turn, is driven by the aircraft engine. The drive unit is controlled by a frequency and load controller. A voltage regulator regulates the voltage output level of the generator, while a control panel, with its protective circuits and devices, protects the electrical system and components automatically when faults occur by removing the generator from the bus. Both the voltage regulator and the frequency and load controller provide load division during parallel operation of the generators.

Maintenance Requirements. The detailed repair and overhaul of AC generators can be performed by a field maintenance activity or by a depot. Normally, generators are not repaired by organizational maintenance. The extent of repairs that may be performed by a field maintenance activity are determined by the availability of special tools, test equipment, technical orders, parts, and skilled personnel. These resources must be made available before an effective overhaul can be performed at the field maintenance level.

Before repairing or overhauling an AC generator, you must check the applicable technical order. This technical order contains a detailed step-by-step procedure for the task to be performed.

Normally, the generator maintenance performed by field personnel includes: cleaning; inspecting; bench check of units and components; making insulation breakdown tests on windings and leads; and replacing of bearings, brushes, and rotor assemblies. When a kit is supplied for the repair of a generator, it contains all the necessary parts for what is considered as normal wear and tear maintenance.

It sometimes becomes necessary for a field maintenance activity to set up facilities to completely rebuild the AC generators because of either a shortage in supply or a high-usage rate. In case the facilities must be set up, most of the required equipment such as an oven for baking and drying insulation, special tools, and jigs can be obtained through supply channels. It is not unusual for maintenance personnel to fabricate other special tools to accomplish this type of maintenance. This equipment, the repair kits, and skill all enable the field maintenance activity to turn out completely rebuilt AC generators of the highest quality.

Since there are numerous types and models of AC generators, we will not attempt to discuss the overhaul of a specific one. We do stress the importance of following the technical order for the unit.

The actual tests performed on each generator vary between generators. These tests generally include a method of checking stability of regulation at both minimum and maximum speed under no-load and full-load conditions. Immediately following these checks and while the generator is still hot, a dielectric test is generally made. An insulation breakdown tester or a source of high-voltage AC, as specified in the technical order, can be used for this check. The dielectric test will point out possible insulation breakdowns that could occur when the generator reaches normal operating temperatures.

Exercises (236):

1. a. DC is supplied from the integral exciter to the AC generator field by means of what two components?

   b. The above DC maintains what type of field in the generator?

   c. The rotating magnetic field following the rotor extends outward and cuts through the armature windings, which are located where?

2. a. The brushless-type generator is really a three-in-one unit. What are the three separate and distinct generators in the one unit?

   b. The output of the permanent magnet generator is fed into what circuit prior to going into the exciter generator?

3. a. Inverse voltages and negative voltage spikes have an adverse affect on generator operation, and this is compensated for by use of what components?

   b. What do the capacitors identified above do?

   c. When do the capacitors (identified in "b" above) go into operation?

4. What are the purposes of the PMG?

5. How are brushless generators cooled?

6. How is the speed of a constant-frequency generator controlled?

4-2. AC System Components

In this section, you will learn the various control and protective devices that make up a constant-frequency AC generator system. Foldout number 1 shows a generator control system with the necessary control components; however, the constant-speed drive (CSD) is not included.

A complete and thorough knowledge of how the system and control components operate is vital to the successful performance of your job as an aircraft electrician. For example, you will often be required to perform an operational check of a generator system. If you don't know how the system operates under normal conditions, you can see that it would be very difficult to detect any abnormal conditions. It is not enough that you know that a drive unit is used with a constant-frequency system or that a certain type of voltage regulator is used with a certain generator. You must have an intimate, working knowledge of how these units operate, when they operate, and what effect they have on a system when they do not operate. We begin our discussion with the CSD.

237. Specify conditions and parts of the hydraulic CSD.

Hydraulic Constant-Speed Drive (CSD). The CSD is an hydraulic mechanical transmission that converts variable engine speed to a constant 6,000-rpm output to drive a generator. The type of CSD used to drive the 40-kVA generator will be used as a model in the discussion. The input power to the unit is taken from the engine accessory section through a universal fitting. The AC generator, connected to the output of the drive unit, rotates at 6,000 rpm. Although the CSD is an hydraulically operated unit, it is important that you understand the principles by which it operates.

Operational fundamentals. Figure 4-5 shows a schematic of a typical CSD unit. Oil pressure supplied by the two charge pumps hold the pump piston rods against the variable pump wobbler, and stroking occurs when the cylinder block assembly is rotated. The pump unit volumetric displacement is varied by changing the angle of the variable pump wobbler plate. Changing the angle of the variable pump wobbler changes the reciprocating action of the pump pistons and causes the oil to be transmitted through the port plate to the hydraulic motor.

The fixed displacement motor unit consists of the motor block assembly and the motor wobbler plate. The oil pressure delivered through the port plate from the pump forces the pistons of the motor against the motor wobbler. The force the pistons exert on the motor wobbler is determined by the pump output; the greater the pump output, the greater the force exerted by the motor pistons against the motor wobbler as the cylinder block rotates. The motor wobbler, which is free turning, is connected to the output gear and clutch section to drive the generator. Thus,

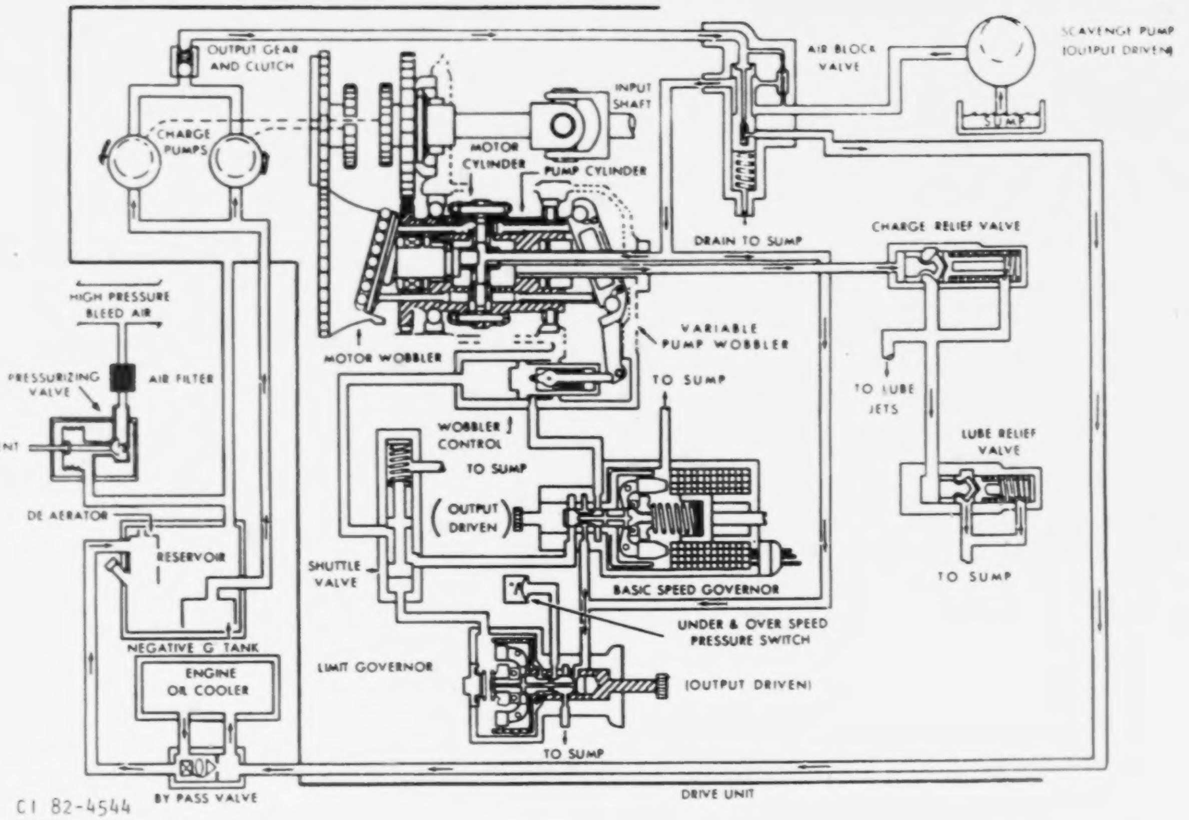
OUTPUT GEAR AND CLUTCH
CHARGE PUMPS
MOTOR CYLINDER
INPUT SHAFT
PUMP CYLINDER
AIR BLOCK VALVE
SCAVENGE PUMP (OUTPUT DRIVEN)
SUMP
DRAIN TO SUMP
CHARGE RELIEF VALVE
HIGH PRESSURE BLEED AIR
VARIABLE PUMP WOBBLER
MOTOR WOBBLER
PRESSURIZING VALVE
AIR FILTER
TO SUMP
TO LUBE JETS
VENT
WOBBLER CONTROL
TO SUMP
LUBE RELIEF VALVE
OUTPUT DRIVEN
DE AERATOR
RESERVOIR
SHUTTLE VALVE
BASIC SPEED GOVERNOR
TO SUMP
UNDER & OVER SPEED PRESSURE SWITCH
NEGATIVE G TANK
ENGINE OR COOLER
LIMIT GOVERNOR
(OUTPUT DRIVEN)
TO SUMP
BY PASS VALVE
DRIVE UNIT
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Figure 4-5. CSD schematic.

the linear piston action is converted to rotary motion.

Before you learn how the output of the drive is varied by changing the angle of the variable pump wobbler, let us discuss some of the conditions under which the drive operates. There are three distinct phases in the operation of the drive. One occurs when the drive is accepting input rotation and stepping it down. This is known as *underdrive*. Another occurs when the drive is accepting input rotation and stepping it up. This is known as *overdrive*. Another phase is *straight drive* when the input rotation drives the cylinder block at a rate that requires no modification. Now, let's examine each of these phases in detail.

a. Underdrive. When the variable pump wobbler is moved to the *underdrive* position, which is the position opposite to that shown in figure 4-5, the output speed of the motor wobbler becomes less than the speed at which the cylinder block is being rotated by the aircraft engine. The angle that the variable pump wobbler now assumes is such that the ratio of displacement of the motor is greater than that of the pump. In this condition, the pump ceases to supply working pressure to the motor. This allows the motor pistons to stroke under the influence of the reactive torque (load) of the generator, and oil is displaced to the pump. The motor wobbler is then driven at a slower speed than the cylinder block.

b. Overdrive. When the cylinder block rotation is below the required 6000-rpm output, the variable pump wobbler assumes an *overdrive* position, as shown in figure 4-5. With the variable pump wobbler in this position, the displacement of the variable pump pistons is greater than the displacement of the motor. Pumping of oil then takes place from the pump to the motor, and the n in figure 4-5. With the variable pump wobbler in this position, the displacement of the variable pump pistons is greater than the displacement of the motor. Pumping of oil then takes place from the pump to the motor, and the reciprocation of the motor pistons exerts a positive thrust upon the face of the motor wobbler. This thrust forces the motor wobbler to increase its rotation above the rate at which the cylinder block is being rotated. In this way, the linear thrust of the pistons is translated into additional rotary motion of the motor wobbler, and the output rotation exceeds the input rotation. In this manner, the transmission, by hydraulic action, adds to the input rotation speed.

c. Straight drive. When the input to the transmission equals the desired 6000-rpm output, the variable pump wobbler assumes a *straight drive* position. This angle is such that, neglecting piston blowby, there is no reciprocating of the pistons and no displacement. In this phase, rotary motion is transmitted through the transmission without gain or loss, and is simply a coupling between the aircraft engine and the generator.

The governor system has two functions: (1) to control the drive output speed and thereby the generator frequency, and

(2) to equalize the load between generators operating in parallel. The drive governor system consists of the wobbler control, the basic speed governor as shown in figure 4-5, and the unit known as a frequency-and-load controller (not shown). The arrangement and operation of these units make it possible to accurately control the angle of the variable pump wobbler and hence to control the output speed of the drive.

The wobbler control shown in figure 4-5 operates in conjunction with the basic speed governor to position the pump wobbler in response to speed changes.

The basic speed governor is a spring-biased, flyweight-type governor. It is driven from the output gears of the drive and senses variations from the desired 6000 rpm.

The term "basic speed governor" is derived from the fact that the metering piston, that directs oil to either side of the wobbler control, is spring-biased so that it establishes a basic generator frequency of 395 Hz. In this manner, if electrical control of the drive is lost, the system will drop to 395 Hz. Since 395 Hz is only a reference frequency, some means must be provided to adjust and maintain the frequency at the desired 400-Hz point. This is the purpose of the frequency-and-load controller. The frequency-and-load controller is a device that senses deviations from the desired frequency and the amount of load on the generator, and adjusts the basic speed governor by applying a signal to the magnetic trim head so that the variable pump wobbler is positioned at the correct angle to maintain the output of the drive within the desired limits.

The drive shown in figure 4-5 adjusts the basic speed governor magnetically. In this basic speed governor, the flyweights are alnico slugs soldered to the shoe of a standard flyweight. A trim coil is mounted in the governor head directly above the flyweights. The coils receive signals from the frequency-and-load controller and magnetically trim the speed of the drive by adding to or subtracting from the centrifugal force of the flyweights.

Now that you are familiar with the normal operation of the drive, we shall turn to some of the abnormal operating conditions, such as overspeeding and underspeeding.

The limit governor is the second of the two flyweight governors (see fig. 4-5). It is a protective device and it serves two purposes: It places the drive in a full underdrive condition in case of an overspeed or underspeed of the output, and it automatically removes the generator of that particular drive from the load. The units concerned with protecting the drive from over/underspeed conditions are the limit governor, the underspeed and the overspeed pressure switch, and the shuttle valve. These units, in conjunction with the basic speed governor, control oil pressure to either side of the wobbler control.

The drive is considered to be in an overspeed condition when its output speed is in excess of approximately 7000 rpm. In normal operation (6000 rpm output range), the limit governor and the shuttle valve have no affect on the system. Although the flyweights rotate, they do not exert enough force on the metering piston inside the limit governor to overcome the spring tension exerted on the piston.

As the speed of the drive increases above approximately 7000 rpm, the flyweights of the limit governor move farther apart and adjust the metering piston to a position which allows the oil supply to both the shuttle valve and the pressure switch to drain into the sump of the drive. When the oil is drained from the shuttle valve, the spring inside the shuttle valve forces the valve stem downward. This action effectively shuts off the oil supply to the overdrive side of the wobbler control and also drains the remaining oil out of the overdrive side. Now, the oil supplied through the limit governor forces the wobbler control into the maximum underdrive position (negative angle) and the drive starts to slow down. At the same time, when the oil pressure was drained from the pressure switch, the generator was de-excited and that generator was removed from service. A shutdown caused by an overspeed condition is an irreversible process because the charge pumps will maintain enough pressure to keep the shuttle valve in the *down* position and the pump wobbler remains in the maximum *underdrive* position. The drive cannot be recycled until the engine has completely stopped.

The drive is considered to be in an underspeed condition when the output speed drops below approximately 4500 rpm. Under this condition, the limit governor flyweights move farther in and (as in an overspeed condition) the shuttle valve stem moves down; the oil is from the overdrive side of the wobbler control, the pump wobbler moves to a negative angle, and the oil is ported from the underspeed and overspeed pressure switch. The only difference between an overspeed shutdown and an underspeed shutdown is that, in an underspeed shutdown, the drive can recycle itself if the speed is brought back to normal. The drive and generator can be returned to operation if the drive shuts down because of an underspeed condition, but cannot be used again in flight if the drive has shut down because of an overspeed condition.

The clutch is a one-way device through which the generator connects to the output gear section of the drive. It is a sprag-type unit that prevents an overrunning or motorized generator from damaging the drive. As long as the drive is turning the generator, the clutch is engaged. If, for some reason, the generator is being motorized or is turning faster than the drive, the clutch is disengaged and allows the generator to run free.

Some late model drives have decoupling circuits that enable the input to the drive to be completely disconnected from the aircraft engine if a drive malfunction occurs.

The typical CSD we have just described is designed to operate a 40-kVA AC generator. This drive can best be described as a "linear" drive to distinguish it from a newer type of CSD that uses radial-type pumps.

Maintenance. Only limited repair of a CSD is authorized at field level. If your shop does not have the basic field test stand, no attempt should be made to repair any of the drive components.

The main housings of the drive should not be opened under any circumstances. Internal servicing of the CSD requires controlled environmental conditions and special test equipment and tools not generally available to your shop. Only those parts listed in the replacement parts chart of the technical reference for the particular drive on which you are working should be removed and replaced or repaired. You will usually find that repairs will be limited to such items as oil filters, pressure switches, external plumbing and, in some cases, governor assemblies. When repairing, overhauling, or modifying the CSD, pay special attention to the WARNINGS and CAUTIONS mentioned in the technical orders you are using.

Exercises (237):

1. When is a drive considered to be in an underdriven condition?

2. In what condition is the drive when the variable pump wobbler assumes a positive angle? A negative angle?

3. When is a drive considered to be in an overdrive condition?

4. When is a drive considered to be in a straight-drive condition?

5. What are the functions of the drive governor system?

6. What means is provided to adjust a basic speed governor to maintain the generator frequency at 400 Hz?

7. What are the functions of a limit governor?

8. Generally, repair to the CSD is limited to what four items?

9. What piece of equipment is essential if any repair of drive components is to be attempted?

10. How can you determine which faulty parts you may remove and replace with a good item?

238. Cite functions and characteristics of the frequency-and-load controller and the automatic paralleling unit.

Frequency and Load Controller. There is a frequency-and-load controller for each generator. It senses the real load deviation (both magnitude and direction) from the average real load shared equally or balanced among the generators operating in parallel. The controller supplies a signal to the speed-governor setting on the generator drive to correct any deviation of the generator from the average load.

The controller senses the generator frequency through a frequency discriminator circuit and controls the drive from the output of the magnetic amplifier section. The real load is sensed by the current transformer assembly which is attached to T3 on the generator feeder line, as shown in figure 4-6. The current transformer assembly is part of a load-division loop between generators operating in parallel. The load-division loop may be interconnected for parallel operation through the bus tie and generator breaker contacts. On some aircraft, the controller load input signals are balanced by interconnection of the signal input circuits while, on others, they are interconnected through an equalizing loop. Any real load unbalance between the generators is sensed by a network of current transformers. This network is also known as the load-division loop. It will produce currents in the equalizing circuits which cause the controllers to reposition the frequency control on the drives in a direction to correct the load unbalance. Thus, each controller has two circuits, (1) the frequency control and (2) the load control. These circuits operate through a magnetic amplifier to control the frequency of their respective generators and divide the real load between paralleled generators. Let's follow the schematic in figure 4-6 and discuss how the controller functions.

A reference voltage for load sensing is provided at the output of a load-control circuit. The source of this voltage is the excitation winding (terminals 1 and 2) of the magnetic amplifier which is connected to T3 of the generator output and to ground. An auxiliary power winding then supplies an AC voltage to diodes CR1 and CR2 from terminals 12 and 15 with the circuit being completed through terminals 13 and 14. The load-control circuit, made up of CR1, CR2, R2, R3, R10, and C1, provides a DC signal whose magnitude and polarity are dependent upon the magnitude and polarity of the current transformer load-loop signal. This signal is impressed on resistor R13.

In operation, R10 is adjusted so that the load-control circuit provides zero output when no signal appears on R13. The AC signal from the current transformer load-division loop enters the load-control circuit across R13 and R15. These two resistors form a voltage divider circuit. When the AC signal of R13 is in-phase with the voltage on T3 of the generator, it adds to the voltage across one resistor and the same side of R10, and subtracts from the voltage across the other resistor and the other side of R10. The situation is reversed when the AC signal on R13 is out-of-phase with the voltage on T3 of the generator. The net voltage across R2, R3, and R10 is the difference between the opposing voltages on the upper and lower halves. Thus, the resultant

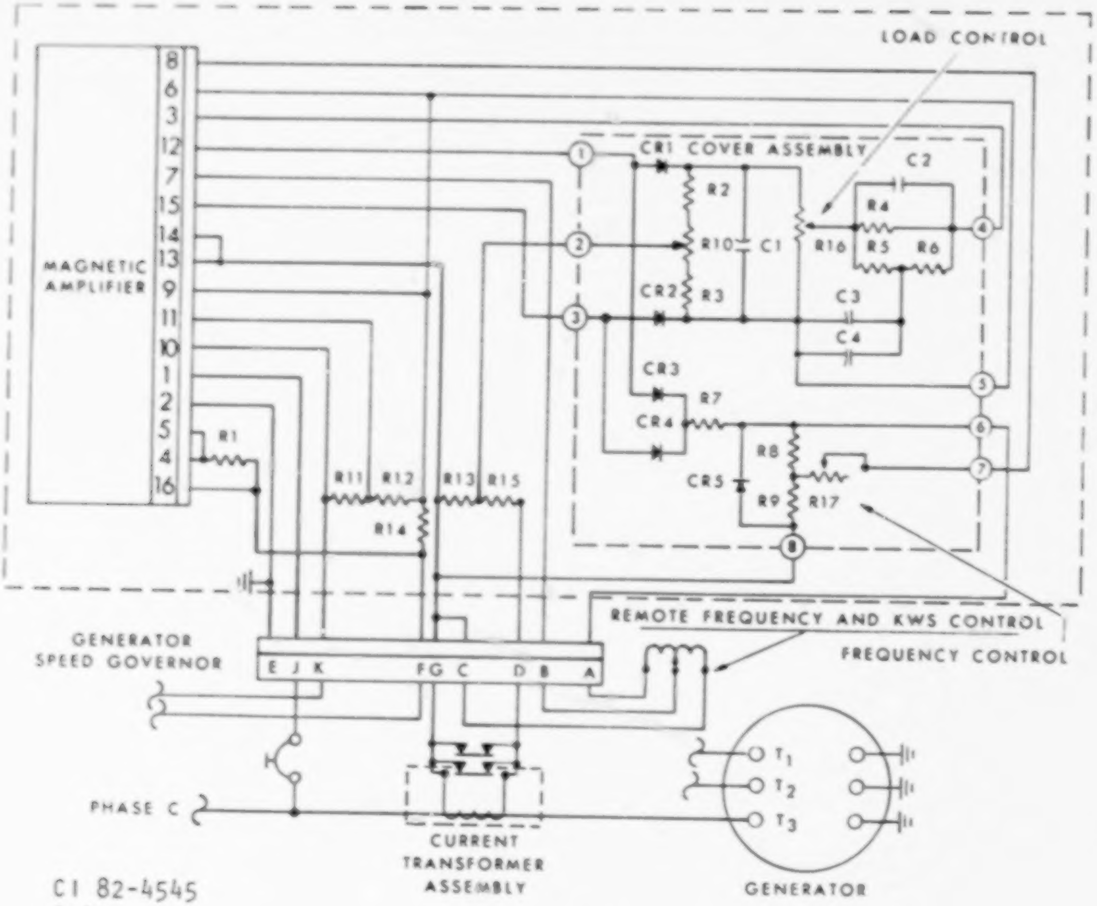

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Figure 4-6. Frequency-and-load controller.

voltage will increase as the generator-load unbalance increases and decrease as the generator-load unbalance decreases. This voltage is then applied to a compensation network. This is a lead-lag circuit composed of C2, C3, C4, R4, R5, and R6. The purpose of this circuit is to improve the response of the system to sudden changes in generator load and to boost the gain of the controller when the error signal is small. This prevents oscillatory motion or "hunting" of the speed governor in response to large error signals and ensures rapid corrective action when the error signals are small. Resistor R16 can be adjusted to vary the steady-state gain on the controller. The output of the compensation network is applied to a control winding (terminals 3 and 6) of the magnetic amplifier. The magnetic amplifier boosts this DC signal and produces a DC output which is applied to the trim coil of the generator speed governor. The magnitude and polarity of this output are dependent upon the magnitude and polarity of the DC input. The output of the magnetic amplifier appears across the generator speed governor and resistors R11 and R12.

During normal operation, an AC voltage from the auxiliary power winding is applied to a full-wave rectifier circuit consisting of CR3, CR4, and R7. The resulting pulsating DC voltage is then impressed across R8, R9, and R17, and the remote frequency and real-load control. This circuit forms a bridge which makes it possible to apply a DC signal to a control winding (terminals 7 and 8) of the magnetic amplifier. This signal, in turn, provides a bias voltage to the trim coil which may be varied with the frequency control potentiometer. The affect of this bias is to control the frequency of the generator output.

Automatic Paralleling Unit. The automatic paralleling unit automatically controls closing a selected generator breaker for paralleling operations. The phase "A" voltage of the incoming generator (unit selected) and the phase "A" voltage of the generator(s) on the bus tie are compared by a phase-sensing circuit in the automatic paralleling unit. When the two voltages are in-phase, a relay in the automatic paralleling unit closes the generator circuit breaker to parallel the machines. Under steady-state conditions of load and input speed, the drive maintains the generator frequencies at 400 ± 1 Hz if the frequency and kWS control on the electrical control panel is at its midpoint of travel. The frequency and kWS control provides a generator-frequency variation of ± 2 Hz. The automatic paralleling unit will operate only if the generators to be paralleled are slightly out-of-phase.

The frequency difference between the generators must be two cycles per second or less. Therefore, it may be necessary at times to reposition the frequency and kWS

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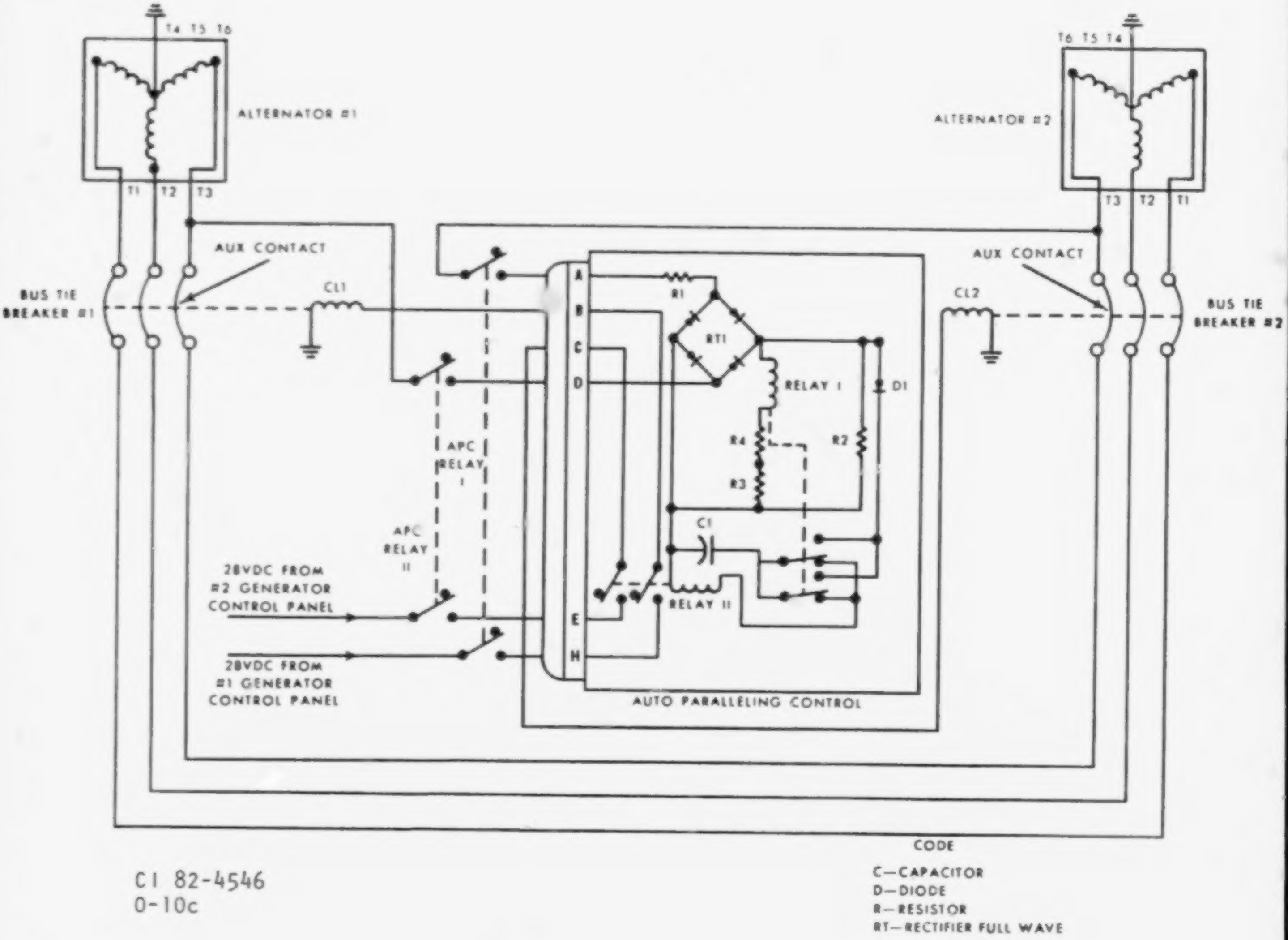
T4 T5 T6
ALTERNATOR #1
T1 T2 T3
T6 T5 T4
ALTERNATOR #2
T3 T2 T1
AUX CONTACT
BUS TIE BREAKER #1
CL1
AUX CONTACT
CL2
BUS TIE BREAKER #2
A
B
C
D
E
H
R1
RT1
RELAY I
D1
R4
R2
R3
C1
RELAY II
APC RELAY I
APC RELAY II
28VDC FROM #2 GENERATOR CONTROL PANEL
28VDC FROM #1 GENERATOR CONTROL PANEL
AUTO PARALLELING CONTROL
CODE
C—CAPACITOR
D—DIODE
R—RESISTOR
RT—RECTIFIER FULL WAVE

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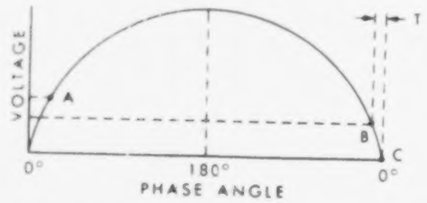
Figure 4-7. Automatic paralleling unit.

control to bring the two generators to within two cycles per second. When there is no voltage on the bus tie, the automatic paralleling unit does not affect control of the generator breaker due to automatic paralleling control relay action. The control relay transfers generator close-coil control between the generator breaker switch and the automatic paralleling unit. The relay is energized by power from the bus tie through the VOLTMETER-SYNCH LIGHT-FREQ METER circuit breaker on the main AC power panel.

Now, let's take a look at how this is accomplished. The automatic paralleling unit is connected in the generator control circuit as shown in figure 4-7.

The paralleling circuit works at a maximum difference in frequency of 4 cps between the two AC generators (generators 1 and 2 of fig. 4-7). Full-wave rectifier RT1 is connected to the same phase on each AC generator output. The output of this rectifier is connected to relay I. The voltage between the two phases depends on the phase angle between the two phases. At a difference of 180°, the voltage will be at its maximum, twice the phase voltage. When the phase difference is zero degrees, the voltage difference will also be zero. As this voltage rises, the output voltage of RT1 rises (see fig. 4-8). Relay I actuates (point A) and connects capacitor C1 in series with diode D1 across the rectifier. C1 charges through D1 to the maximum voltage across the rectifier. D1 prevents C1 from discharging during the time the voltage is decreasing from the peak value to point B. When the voltage output of the rectifier drops sufficiently (point C, fig. 4-8), relay I de-energizes and C1 discharges through relay II. Relay II actuates and causes the DC voltage at pins E and H to be connected to pins C and B of the APU. This DC voltage is applied to circuit breakers which parallel the generators. R2 protects rectifier RT1 by limiting the current through the rectifier. R3 and R4, when properly jumpered, permit relay I to actuate at the correct phase difference. The delay time (T) indicated in figure 4-8 allows relays I and II sufficient time to act before the generators are to be paralleled.



A POINT WHERE RELAY #1 ENERGIZES
B POINT WHERE RELAY #1 DE-ENERGIZES
C OPTIMUM PHASE ANGLE FOR PARALLELING
T DELAY TIME OF RELAY #2 PLUS CIRCUIT BREAKER

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Figure 4-8. Time curve

Exercises (238):

1. What is the key component in controlling kW load division?

2. What is the purpose of the frequency-and-load controller during isolated generator operation? During parallel operation?

3. How is the amount of load on a generator sensed?

4. On the CSD, where are the frequency-control signals applied?

5. What is the purpose of the frequency-discriminator circuit in the 40-kVA frequency-and-load controller?

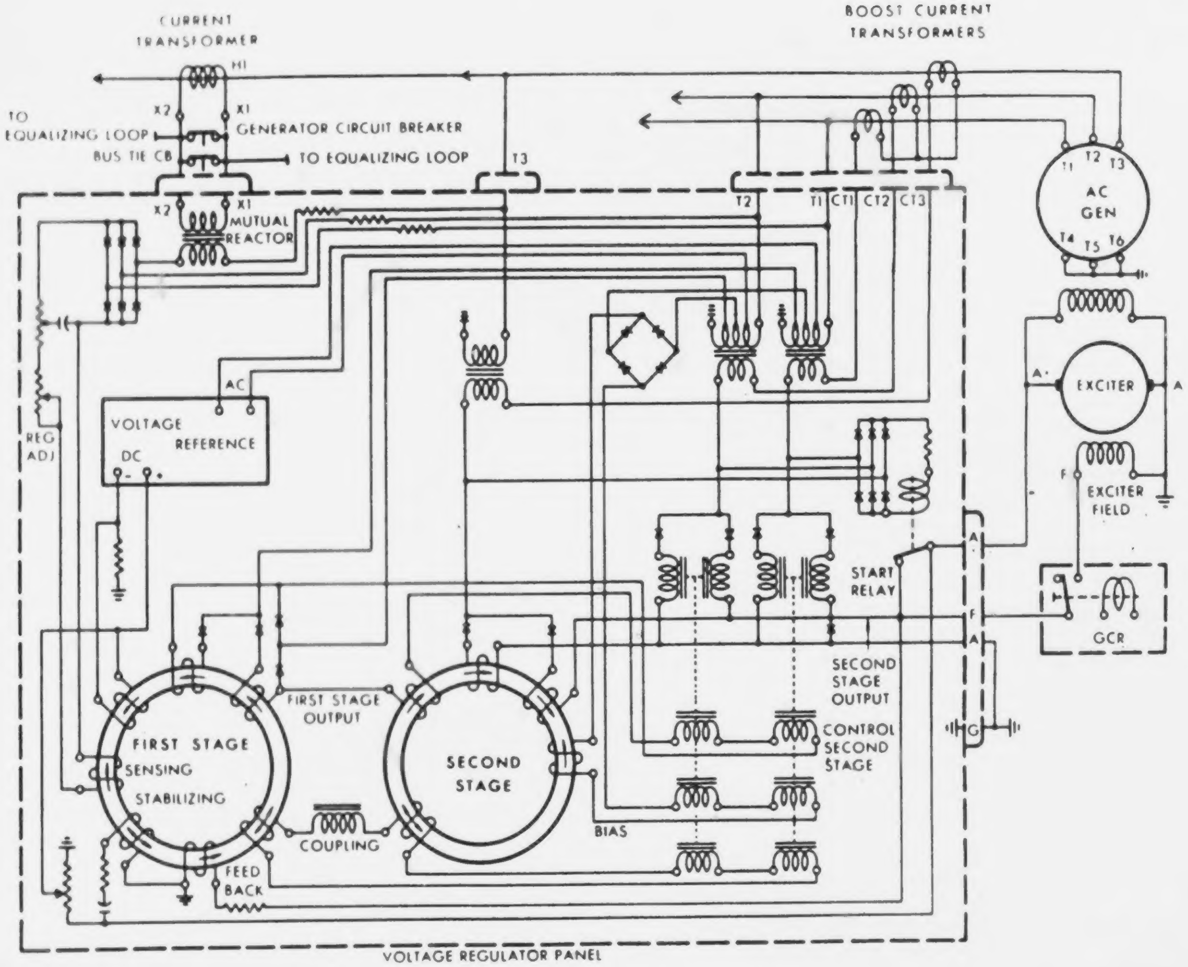
6. In respect to automatic paralleling, what two-phase voltages are being compared by a phase-sensing circuit?

7. What condition is necessary for the automatic paralleling unit to operate?

8. After the automatic paralleling unit is operating (a comparing by the phase-sensing circuit) and when the two voltages become "in-phase," what then takes place?

239. State the function of various components in the voltage regulator.

Voltage Regulator. A MAG-AMP voltage regulator operates on the principle of a saturable reactor. A typical MAG-AMP voltage regulator is shown schematically in figure 4-9. This is a closed-loop voltage regulator system, and the sensing circuit supplies a signal proportional to the average of the 3-line voltages to a DC-control winding. (Note the sensing circuit of fig. 4-9.) The voltage regulator, through its control circuits and its output to the exciter shunt


CURRENT TRANSFORMER
H1
X2
X1
TO EQUALIZING LOOP
GENERATOR CIRCUIT BREAKER
BUS TIE CB
TO EQUALIZING LOOP
T3
BOOST CURRENT TRANSFORMERS
T1
T2
T3
AC GEN
T4
T5
T6
X2
X1
MUTUAL REACTOR
T2
T1
CT1
CT2
CT3
A-
EXCITER
A
REG ADJ
AC
VOLTAGE REFERENCE
DC
F
EXCITER FIELD
START RELAY
A
F
A
GCR
SECOND STAGE OUTPUT
CONTROL SECOND STAGE
G
FIRST STAGE OUTPUT
FIRST STAGE
SENSING
STABILIZING
SECOND STAGE
COUPLING
BIAS
FEED BACK
VOLTAGE REGULATOR PANEL

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0-10c

Figure 4-9. MAG-AMP voltage regulator.

field, tends to minimize any error, attempting to keep the generator output voltage constant. This signal is compared magnetically to the reference signal (the reference signal is constant over a large range of generator output) in the first-stage magnetic amplifier. The resultant value of magnetic flux of the reference signal and the sensing signal is called generator error, and this error controls first-stage output. The output of the first stage is used to power the control winding of the second stage and thereby control second-stage output to the shunt field of the exciter generator. The first-stage magnetic amplifier uses additional windings which assist in the control of the output circuit.

The first-stage output is fed into a second-stage DC control winding, which is compared to a bias signal. The bias circuit is very similar to the reference circuit, except that the bias circuit signal is variable and is proportional to the line voltage. The magnetic resultant bias and the first-stage output signals control the second-stage output voltage. The second stage is called the power stage, and it supplies the DC power to the exciter field. The amount of DC power (excitation) supplied to the exciter, controls the level of output voltage of the AC generator.

To maintain a stable system, a feedback network as shown in figure 4-9 is necessary. This circuit takes a rate-of-change signal from the exciter output voltage, A+ to A−, and feeds it into a control winding of the first stage. This signal is in such a direction as to oppose any change which occurs due to transient load conditions.

To obtain output power for the exciter field from the voltage regulator, AC generator output is required as the input power to the voltage regulator. A starting relay is used to permit generator buildup without voltage regulation. This is accomplished by using normally closed circuits connected from A+ to F through the generator control panel. This allows the generator exciter to use self-excitation to build up the AC generator voltage so that the power is available for use in the regulator. As soon as the AC generator builds up to 195 volts line-to-line, the start relay contacts are opened. This, then, allows the voltage regulator to take control of the system.

Boost current transformers, one located on each phase lead (see fig. 4-9) and connected to the regulator through terminals CT1, CT2, and CT3, are used to boost or compound the regulator output during overload and short-circuit conditions. The rated voltage output of the generator is required under all conditions, including that of overload. The boost current transformers increase the regulator maximum output limit by increasing the voltage supplied to the second-stage magnetic amplifier output circuit. When the system is operating at rated voltage, the regulator controls the excitation to the exciter field as required to maintain the system voltage constant. The boost current transformers are used only to extend the maximum output limit of the regulator. During 3-phase, short-circuit conditions, the voltage drops to a low value outside the limits of the voltage regulator. When this occurs, there is no control of the AC system except by the boost current transformers which are designed to supply the rated short-circuit current. Three-phase short circuits are primarily controlled by the design of the boost current transformers and the generator. The voltage developed across the boost current transformers during 3-phase short circuits maintains the voltage on the starting relay coil so that the contacts remain open when the line-to-line voltage drops below relay-closing voltage and thereby prevents the voltage regulator from cycling.

Under varying load conditions, the generator winding temperatures increase and consequently cause generator losses to increase due to the increased resistance. In order to maintain very closely regulated voltage, a trimming circuit or positive feedback circuit is used. This circuit senses the exciter output voltage from A+ to A−. A resistor is added to the feedback circuit so that the circuit boosts the regulator output when required at loads of 50 percent and above.

When the several generators are operating in parallel, the voltage regulators function to control the division of reactive load (kVAR), and they have only a negligible effect on the division of real load (kW). As you know, real-load division is controlled by the speed governors of the generator drives.

A current transformer (see fig. 4-9), whose primary is the power lead (T3) from the generator, has its secondary connected to X1 and X2 on the regulator which, in turn, is connected to the mutual reactor in the sensing circuit of the voltage regulators. It is essential that the current transformer be connected exactly as shown, and that it be placed on the power lead T3 (C phase) with the H1 end of the transformer directed toward the generator. The X1 and X2 terminals of the current transformer are connected into an equalizer loop (fig. 4-9), which is a series-parallel loop with the X1 terminals of one current transformer connected to the X2 terminals of the current transformer of the next generator in the parallel system. The diagram shows that one of the auxiliary switches of the generator circuit breaker is connected to short circuit terminals X1 and X2 of the current transformer when the circuit breaker is open. Thus, a generator-regulator unit that is disconnected from the bus will not affect the regulated voltage in the rest of the AC system.

The reference circuit in this regulator supplies a constant output DC which is used as the name infers. This reference is a completely static device which is not sensitive to normal operating frequency changes and normal voltage changes. If, during normal operation, the reference signal (34 to 38 milliamperes) is lost for any reason, the voltage regulator output will go to minimum. When this happens, the system voltage will cycle because of the opening and closing of the starting relay contacts as the system voltage rises and falls. The system voltage will go to approximately 200 volts and then fall off to 100 volts, cycling at a frequency of 5 to 10 Hz.

The sensing circuit applies a 57-volt DC signal, proportional to the average of the three AC phase-to-phase voltages, to a control winding of the first-stage magnetic amplifier. This signal is in such a direction as to oppose the signal supplied by the reference circuit and tends to drive the first-stage output to minimum. If, for any reason, the sensing signal (28 to 35 milliamperes) is lost, the regulator output goes to maximum, forcing the output voltage of the system to go to maximum, which is approximately 300 volts at 400 Hz with no load on the generator. Faulty rectifiers in this circuit usually cause the voltage level of the system to go high, since they decrease the DC output signal.

The power transformers provide the power required by the regulator. The primary power of the power transformer is wye-connected with all three phases tapped. T1 is tapped at 70 volts line-to-ground (neutral) to supply the voltage for the second-stage bias circuit. T2 is tapped at 30 volts phase-to- ground to supply the AC power for the first-stage magnetic amplifier. T3 is tapped at 120 volts phase-to-ground in order to supply the power for the reference circuit.

The boost current transformers are used to supply the voltage required by the second-stage amplifier during short-circuit conditions. The secondary voltage of a current transformer will be approximately 20 volts at 200 percent short-circuit current. If the current transformers are not connected, the regulator will not have sufficient power for the magnetic amplifier power circuit and, therefore, the system will cycle as if there is no reference current. If the current transformers are connected in reverse, there will be a decreasing system voltage as load is applied to the generator.

The starting relay is used to short out the regulator, complete the exciter field circuit, and allow the generator to build up under self-excitation. The opening voltage of the relay is approximately 195 volts phase-to-phase. Should the relay have an open coil or welded contacts, the power system will go to overvoltage, 300 volts at 400 Hz. On the other hand, high-resistance contacts will keep the generator from building up. With the incorporation of a field flashing circuit, there should be no problem with high-resistance contacts.

The bias circuit is used to bias the second-stage magnetic amplifier to minimum, opposing the first-stage output power. The output of the bias circuit is approximately 32 milliamperes. Should this signal be lost, the regulator output will tend to be high, forcing the system voltage high.

The first-stage magnetic amplifier is a self-saturating, single-phase, full-wave, magnetic amplifier. Of the two stages of magnetic amplification, the first stage is the more important since it determines what happens to the system voltage during normal operating conditions. The second stage is used only for power amplification, whereas the first stage not only amplifies, but also receives all of the converging system signals which cause the voltage regulator to maintain a constant generator output voltage. The most common failure in the first stage is probably in one of the rectifiers. Complete failure of rectification can cause the regulator output to go to zero. If one saturating rectifier fails, the regulator will indicate instability. Other failures such as an open winding or shorted turns are very unlikely.

The second-stage magnetic amplifier is a three-phase, self-saturating, full-wave type. This is the power stage and it is controlled by the first stage in such a manner that the power supplied to the generator exciter is regulated to maintain rated system voltage.

The commutating rectifier consists of a half-wave, 60-volt cell connected across the output of the second-stage magnetic amplifier in parallel with the shunt field of the exciter. This rectifier, connected across the inductive load, improves the response time of the regulator. When this rectifier is open, the system voltage will collapse, since there would then be a dead short across the shunt field.

The only maintenance that can be done at field level is the testing of the regulator. The regulator is tested on the T–35 tester.

Exercises (239):

1. The MAG-AMP voltage regulator's sensing circuit supplies what type of signal?

2. What is the error that controls first-stage output?

3. a. The circuit that takes a "rate-of-change" signal from the exciter output voltage, A+ to A−, (fig. 4-9) and feeds it into a control winding of the first stage is what type of circuit or network?

   b. How does the signal in the above circuit aid in maintaining a stable system?

4. Why is a feedback circuit used in the first stage of a magnetic amplifier voltage regulator?

5. What is the key component in controlling kVAR load division?

6. If the boost current transformer (used with the magnetic amplifier voltage regulator) had its connections to the voltage regulator reversed, what would be the result?

240. Specify how the components in the generator control panel are used.

Generator Control Panel. The typical control panel selected for this discussion contains the necessary relays and sensing units to perform such functions as generator field flashing, generator exciter control, anticycling, and overvoltage protection. It also contains overexcitation and underexcitation protection, underspeed protection, exciter protection, and fault-protection circuits.

We shall discuss each of the components in the control panel and see exactly how and when each unit operates. Later in this volume, you will see how the generator control panel in an operating system functions in conjunction with the other units of a generator system. Refer to foldout 1.

The generator control relay (GCR) is used to open or close the exciter field of the generator. It is an electrically operated, mechanically latched relay. The "close" coil of the GCR is connected to the "close" side of the generator switch. Then the generator switch is moved to the CLOSE position, the "close" coil is energized, pulling the contacts into the CLOSED position where they are held in place by a mechanical latch. At the same time, the exciter field of the generator is momentarily flashed.

The trip coil of the GCR is energized by moving the generator switch to the TRIP position or by the operation of certain protective devices within the control panel. When the trip coil is energized, it releases the mechanical latch, and spring tension moves all the contacts into the OPEN position.

The lockout relay is used to prevent generator cycling during a fault condition. The lockout relay coil is connected across the trip coil of the GCR so that both coils are energized simultaneously. Therefore, any control action, manual or automatic, that trips the generator out through the GCR will cause the lockout relay to energize. When energized, the lockout relay interrupts the field flashing circuit and opens the circuit to the "close" coil of the GCR. Since the "close" circuit is complete through the de-energized contacts of the lockout, you can see that, if the generator switch is moved to the CLOSE position while the lockout relay is energized, the only result will be to keep the lockout relay energized as long as the trip fault exists.

An underspeed relay is provided to disconnect the generator from the aircraft distribution system in case the drive goes into an underspeed condition. The ground for the underspeed relay is completed when the underspeed pressure switch on the generator drive closes.

The differential fault relays provide fault protection for the generator and the generator feeder wires. A fault within a generator or in any of the generator feeder wires will result in a greater current flowing in the neutral lead of the faulted phase than flows to the power distribution system through the feeder wires. The sensing of this differential fault is done through ring-type current transformers for each phase, one on the generator neutral lead and one on each of the feeders supplying power to the power distribution system. The neutral and distribution feeder transformers for each phase are connected in parallel across the differential fault relay coils in the generator control panel. During normal operation, the current through the neutral and distribution feeders will be the same; the voltages induced in the two-current transformers of each phase will be equal and opposite, and no current will flow in the relay coil. When a fault occurs, the voltages induced in the two transformers differ by the amount of fault current which produces current flow in the relay coil. A fault causing a 30-ampere differential current will instantly close the differential fault relay contact to trip out the GCR of the faulted generator. This effectively removes the generator from the system.

A balanced three-phase fault on the interconnecting feeder wires when two or more generators are operating in parallel will produce excessive exciter armature voltage and system undervoltage on all the generators. Excessive exciter voltage is sensed by the exciter voltage relay and undervoltage is sensed by the UNDEREXCITATION relay. Both relays energize the heating elements of the thermal time-delay switches. Thermal time-delay switch No 2 will close in from 2 to 4 seconds and isolate that generator from the rest of the system. If the trouble continues, thermal time-delay switch No 1 will close in from 5 to 10 seconds and energize the trip coil of the GCR for that generator.

Protection against excessive reactive current flow in the generators and reactive unbalance in the distribution system is provided by the OVEREXCITATION-UNDEREXCITATION (OE-UE) circuit. The OVEREXCITATION relay and the UNDEREXCITATION relay in each generator control relay automatically controls isolating or tripping the generators in parallel when such malfunctions occur. The OVEREXCITATION relay functions to isolate the defective generator from the remaining generators. The UNDEREXCITATION relay controls tripping the GCR through the thermal time-delay switches. Note that both the UNDEREXCITATION and the OVEREXCITATION relays are energized during normal operation and complete their respective circuits only when de-energized.

The wye-delta transformer and full-wave rectifier are used to supply operating power and the generator reference voltage to the OE–UE relays. The voltage to the relays will be increased or decreased, depending on the amount and direction of the unbalanced reactive current of one generator relative to that of the other generators. This is achieved by connecting a current transformer so that its output is applied to the mutual reactor. The mutual reactor affects one phase of the voltage being applied to the full-wave rectifier. The current transformers and mutual reactors of all the generators are connected into a loop circuit known as the OE–UE loop.

The OE–UE loop functions only when the generators are paralleled together. As long as the reactive load is equally divided, the voltages in the OE–UE loop are balanced and the OVEREXCITATION relay will function only if an overvoltage condition occurs. OVEREXCITATION, which causes reactive unbalance due to excessive reactive current in that generator, will produce a current flow in the mutual reactors. The direction of flow in the OE–UE loop through the mutual reactors produces a voltage that boosts the voltage sensed from the overexcited generator. Consequently, the overexcited generator will be switched into isolated operation by the OVEREXCITATION relay.

UNDEREXCITATION, which causes reverse reactive current flow in a generator, will produce mutual reactor current that opposes the voltage sensed from the underexcited generator so that the UNDEREXCITATION relay drops out. The UNDEREXCITATION relay controls the thermal time-delay switches. Thermal time-delay switch No. 2 places the generator in isolated operation in 2 to 4 seconds, while thermal time-delay switch No 1 will trip the GCR in 5 to 10 seconds.

Exercises (240):

1. What unit is used to open and close the exciter field of a generator?

2. What component is used to prevent generator cycling during a fault condition?

3. What system component detects generator undervoltage during parallel operation?

4. What circuit is used to protect against excessive reactive current flow in the generators or reactive unbalance in the distribution system?

5. Under what conditions does the OE–UE loop circuit function?

4-3. AC System Operation

In this section we will discuss operation and power distribution of an AC generator system. Our detailed discussion of the many AC generator system components will now be put to work. Foldout 1 is a complete AC generator system and is used for our discussion of system operation.

Keep in mind that, as an aircraft electrical system specialist, you must be thoroughly familiar with the AC generator's operating principles and be able to maintain its various control systems.

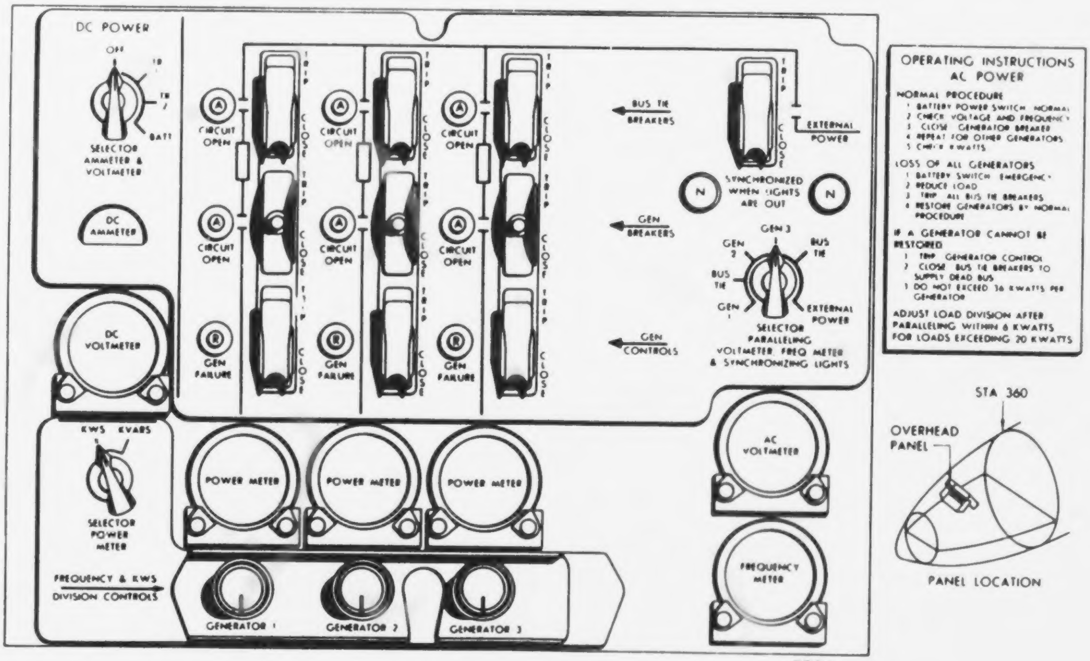
241. Cite operational charactertistics of the AC generator system.

AC Generator System Operation. The generator system we are going to discuss has three 40-kVA generators. Each generator provides a three-phase, 115/200-volt AC output at an essentially constant frequency of 400 Hz.

Description. A frequency-and-load controller unit for each constant-speed drive accomplishes frequency control and real-load division for parallel operation of the generators. The frequency-and-load controller controls the speed governor settings of the generator drive. It also responds to deviations from the desired 400-Hz settings and to changes in real-load unbalance between parallel generators.

Operation. The electrical control of the speed governor is accomplished through a control motor on the drive. Generator voltage control and reactive load division are accomplished by a static-type (magnetic amplifier) voltage regulator unit for each generator. The AC generators provide their own DC power for field excitation through a self-contained DC generator exciter. The voltage regulators control the field current of the exciters to vary the generator field strength and subsequently maintain the generator voltage output at 200 volts line-to-line. Several current transformers are contained in a transformer assembly. They are connected to corresponding phases in each generator to compare current flow of one generator to the other. These transformers provide load sensing, both real and reactive, for the power-meter and load equalizing controls and provide for voltage regulator power boost.

The control switches, selectors, and indicators for the main AC power supply system are grouped on the electrical control panel (fig. 4-10). This panel is a section of the overhead panel. The generator control switches control closing the generator fields and associated circuits necessary to return a tripped generator to service. They also provide the manual control to trip off a generator. The generator breaker and bus-tie breaker switches are the manual controls for opening and closing their respective power breakers. The generator breakers connect the generators-to the load buses. The bus tie breakers connect the load buses to the synchronizing bus tie. Indicator lights, adjacent to the generator control and breaker switches, show the control condition for each generator system. The generator failure lights indicate when a generator is tripped off, which might be done manually or automatically through a protective control. The breaker CIRCUIT OPEN indicator lights are on when their respective breakers are open. The voltmeter and frequency meter are connected to show the voltage and frequency of the source selected by the paralleling selector. The paralleling selector connects the synchronizing lights and automatic paralleling control unit to the circuit of the generator selected for paralleling. The power meters, one for each generator, provide the indication of real load (kilowatts) or reactive load


DC POWER
OFF
TR
BATT
SELECTOR AMMETER & VOLTMETER
DC AMMETER
DC VOLTMETER
CIRCUIT OPEN
GEN FAILURE
TRIP
CLOSE
BUS TIE BREAKERS
GEN BREAKERS
GEN CONTROLS
EXTERNAL POWER
SYNCHRONIZED WHEN LIGHTS ARE OUT
GEN 1
GEN 2
GEN 3
BUS TIE
SELECTOR PARALLELING VOLTMETER FREQ METER & SYNCHRONIZING LIGHTS
OPERATING INSTRUCTIONS AC POWER
NORMAL PROCEDURE
1 BATTERY POWER SWITCH NORMAL
2 CHECK VOLTAGE AND FREQUENCY
3 CLOSE GENERATOR BREAKER
4 REPEAT FOR OTHER GENERATORS
5 CHECK KWATTS
LOSS OF ALL GENERATORS
1 BATTERY SWITCH EMERGENCY
2 REDUCE LOAD
3 TRIP ALL BUS TIE BREAKERS
4 RESTORE GENERATORS BY NORMAL PROCEDURE
IF A GENERATOR CANNOT BE RESTORED
1 TRIP GENERATOR CONTROL
2 CLOSE BUS TIE BREAKERS TO SUPPLY DEAD BUS
3 DO NOT EXCEED 36 KWATTS PER GENERATOR
ADJUST LOAD DIVISION AFTER PARALLELING WITHIN 6 KWATTS FOR LOADS EXCEEDING 20 KWATTS
STA 360
OVERHEAD PANEL
PANEL LOCATION
KWS KVARS
SELECTOR POWER METER
POWER METER
AC VOLTMETER
FREQUENCY METER
FREQUENCY & KWS DIVISION CONTROLS
GENERATOR 1
GENERATOR 2
GENERATOR 3
6384

CI 82-4549
0-10c

Figure 4-10. Multi-engine control panel.

(kilovolt-amperes-reactive) on each generator. Real or reactive load indication is selected by turning the power meter selector to the kWS or kVARS position. The three-frequency and kWS division controls immediately below the power meters are used for real-load division control with the generators paralleled and as a frequency control to synchronize the generators for paralleling.

The majority of the control relays and automatic protective controls for each generator system are contained in the generator control panel. The relays and sensing units necessary to provide the system control functions are also housed in each generator control panel. The control panels also contain a transformer-rectifier unit and voltage indicating relay. The transformer-rectifier (T-R) unit normally supplies the 28-volt DC power for panel functions while the generator is operating. Power is also supplied to the panel from the airplane switched DC bus. The voltage indicating relay energizes only when there is three-phase power applied to the panel, thus preventing residual voltage from an unexcited generator from holding control relays closed.

The generator control relay (see foldout 1) must be closed to establish the exciter field circuit and the generator breaker control circuit before a generator can develop its required output voltage and be connected to its load bus. The generator control switch on the electrical control panel controls closing the generator control relay. With power on the airplane (battery bus energized) and the engine fire switch to NORMAL, moving the generator control switch momentarily to the CLOSE position will cause the generator control relay to mechanically latch. Closing the switch will also transfer power to the exciter field through the flashing resistor. With the generator control relay closed, the relay contacts complete the exciter field circuit, connects control power to the generator breaker switch if the drive is up to SPEED, turns off the generator failure light, and arms the relay trip coil circuit. The field flashing resistor circuit is opened by the voltage indicator relay as soon as generator output powers the control panel. With the generator control circuit established by closing the control relay, the voltage and frequency of the generator can be read on the meters by placing the paralleling selector to the correct GENERATOR position. However, the generator is not supplying its load bus until the generator breaker is CLOSED.

The generator breaker switch on the electrical control panel is the manual control for closing and tripping (opening) the generator breaker. During normal system operation, the generators will be paralleled by closing the generator breakers; the bus tie breakers normally are left closed and are opened only for isolated generator operation or for manual control of paralleling. With power on the synchronizing bus tie, the generator breakers can only be closed through operation of the automatic paralleling unit.

The control transfer between manual and automatic paralleling control of the generator breaker is accomplished by the AUTO parallel control relay which is energized by AC power from the bus tie. With the paralleling selector set to the correct GENERATOR position, operating the generator breaker switch to the CLOSE position will connect the generator output to the automatic paralleling unit. This permits frequency comparison with the generator already on the synchronizing bus, so that the automatic paralleling unit can switch power to close the generator breaker when the frequencies match closely enough in both phase and rate. If there is no generator on the synchronizing bus at the time the generator breaker switch is moved to the CLOSED position, the switch directly controls closing the generator breaker, provided the external power breaker is open. A contact of each generator breaker switch is connected to automatically trip the external power breaker when the switch is moved to the CLOSED position.

During manual paralleling of the generators, the bus-tie breakers are opened and generator breakers are closed to allow the generators to supply individual generator buses until paralleled. The generator to be paralleled must match synchronizing bus voltage and frequency within 5 volts and 2 Hz before the bus tie breaker is closed. Rotating the paralleling selector switch to the applicable position will provide voltmeter and frequency meter readings for the incoming generator and cause the synchronizing lights to operate. The lights will light up and darken as many times per second as there are cycles-per-second difference in frequency between synchronizing bus and generator bus power. The bus tie breaker switch is moved to the CLOSED position when the voltage is within limits and the synchronizing lights go out. During manual paralleling of the generators, the BUS TIE BREAKER switch must not be placed in the CLOSED position unless the following conditions exist: The paralleling selector switch is positioned to the incoming generator and the synchronizing lights are out. Failure to observe these precautions may result in damage to the generator drive due to loads imposed by opposing voltages. If frequency adjustment is necessary before the generator can be paralleled, you may use the frequency and kW division controls on the electrical control panel to make the necessary adjustments.

Normal operating procedures at engine shutdown will cause the generator breaker to automatically disconnect the load buses from the generator. An underspeed switch on the generator drive is set to close and cause the generator breaker to trip when the generator frequency is less than 350 Hz. The underspeed switch closes, energizing the underspeed relay in the generator control panel. (See foldout 1.) This supplies power to trip the generator breaker relay and remove generator power from the bus.

The bus tie breakers and generator control relays will normally remain closed when the system is shut down. Therefore, the next time the engines are started and run, only the generator breakers need to be closed to supply AC power to the load buses and to parallel the generators. The underspeed switch also functions to prevent the generator relay from being closed before the generator drive speed is adequate. The underspeed switch should operate to increased drive speed before the frequency exceeds 370 Hz.

Generator control anticycling is provided through the lockout relay in the generator control panel (foldout 1). This means the lockout relay coil is connected across the trip coil of the generator control relay so that both coils are energized at the same time. Therefore, any control action, manual or automatic, that trips the generator through the control relay will cause the lockout relay to pull in and hold both the control relay close coil circuit open as well as the field flashing circuit. If the generator control switch is being held in the CLOSED position when the trip signal occurs, the lockout relay will be held in by power through the control switch, preventing the generator control relay from reclosing until the control switch is returned to OFF.

An aircraft distribution system is made up of many wires and power boxes located throughout the aircraft. It provides a means of distributing the generator output to all the various loads in the aircraft. The switches and meters used to control and monitor the generator and distribution system are shown in figure 4-10.

The portion of the system between the output terminals of the generator and the main bus is generally referred to as the *generator bus*. When the generator breaker is closed, it connects the output of the generator to the main bus. The main bus is the portion of the distribution system to which the loads are connected. Feeder wires from the main buses go out to various load boxes located throughout the aircraft. The central tie bus is the interconnection between the various main buses. No load is connected to this bus. When external power is connected to the aircraft, it is fed to the central tie bus. Thus, it is necessary to close all the bus tie breakers and connect the main bus to the central tie bus. All aircraft loads may be powered by the central tie bus. During parallel generator operation, all bus tie breakers and all generator breakers are closed, and the total electrical load on the distribution system is shared by the generators.

Exercises (241):

1. a. When generator frequency drops from 400 Hz to approximately 350 Hz, what unit on the generator drive does what?

   b. What sequence takes place when the underspeed switch closes?

2. When the generator control relay closes, what circuit functions take place?

3. In a driven CSD generator system, how is the generator breaker closed?

4. During manual paralleling of the generator, how are the bus tie and generator breakers positioned?

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Power Systems and Motors

TODAY'S MODERN aircraft require various types of power. AC generator powered aircraft require a certain amount of DC, just as DC generator powered aircraft require some AC. A means to convert some of the aircraft's power is therefore necessarily installed in various aircraft. Aircraft that are AC powered make use of transformer-rectifiers for their DC requirements, while DC powered aircraft make use of inverters for their AC requirements.

As an aircraft electrical systems specialist, you should be familiar with the purpose, types, and general maintenance of the motors and transformer-rectifiers mentioned.

In this chapter we will start by discussing external power, transformer-rectifiers, then a battery system, and conclude with a study on various DC and AC motors.

5-1. External Power Systems

The primary purpose of any external power system is to allow ground maintenance personnel to perform operational checks on the electrical and electronic equipment when the aircraft generators are not powering the aircraft buses. The external power system also provides a means for connecting a load bank to the main AC power system. A load bank, when connected to the aircraft, allows electrical maintenance personnel to perform an operational check of the main power system.

242. Explain the operation of a basic external power systems and its components.

There are many external power systems in use today. The multi-engine external power system shown in figure 5-1 is typical for many aircraft. One thing you must keep in mind (and this applies to most external power systems) is that at no time should the aircraft generators and the external power unit generator be paralleled. Due to this restriction, the control system may seem to be very elaborate.

Description. The external power control system consists of the following components: external power receptacle, phase sequence relay, power control relay, power circuit breaker relay, power lockout relay, and the power disarm relay, as shown in figure 5-1. The position indicator, EXT POWER switch, and the BUS TIE ISOLATE switch are located on the AC control panel in the cockpit area.

The external power receptacle provides a means of connecting external three-phase AC power to the aircraft power system. The receptacle is also used to connect a load bank to the central tie bus. Four pins, A, B, C, and N, connect the AC power to the aircraft system. Pin E, through the phase sequence relay, provides the DC control power required for closing the external power control relay. Pin F is used for load bank operation only and provides a ground for the external power disarm relay.

The phase sequence relay is used to prevent external AC power from being connected to the aircraft bus when the phase sequence is incorrect (other than A–B–C or 1–2–3). This relay will be energized if the phase sequence is correct.

The external power control relay is powered by 28 volts DC from the external power cart through pin E and the phase sequence relay.

The external power circuit breaker relay is a latch-type relay of the same type used for the generator breaker and bus tie breakers. This circuit breaker is used to connect and disconnect external power to the central bus. The external power breaker uses three sets of its five auxiliary contacts; one is used to control the "close" and "trip" coil circuit to ground, a second set is used to conrol the external power interlock relay to prevent a generator breaker from being closed before external power is tripped, and a third set is used to conrol the main external power circuit breaker relay position indicator.

The external power lockout relay is energized any time a central tie bus fault occurs. The relay is powered from the aircraft's DC power system. The lockout relay contacts control the external power breaker "close" and "trip" coil circuits.

The external power disarm relay provides a means of connecting an external load bank to the central tie bus when the aircraft generators are operating. Under normal conditions, we don't want the external power control circuit breaker (upper left corner of fig. 5-1) to close when the aircraft generators are on the bus, but, in this case, we do. Pin F of the external power receptacle provides a ground return for the coils of the external power disarm relay when the load bank is connected to the receptacle.

A typical circuit breaker relay position indicator has white bars running vertically and horizontally. The word OFF is also printed on the indicator. When the bar is lined up with the reference on the AC control panel, the circuit breaker is closed; and when the bar is at a right angle to the reference line, the breaker is open. When the word OFF is showing, the indicator is not powered.

Operation. When external power is connected to the external power receptacle, there is 118/205 volts AC applied to the phase sequence relay. If the phase sequence is correct (A–B–C), contacts between A2 and A1 will close (see fig. 5-1). With the phase sequence relay closed, 28 volts DC from pin E will be applied through contacts A2 and A1 to the external power control relay, closing it. When the main external power switch is turned ON (reference lower left corner of fig. 5-1), 28 volts DC from the external power control circuit breaker is applied to the "close" coil of the external power breaker causing it to close. When the external power breaker closes, a set of its controls will energize the external power interlock relay. The interlock relay keeps a generator breaker from closing when external power is connected to the central bus. The interlock relay contacts are in series with the generator breaker "close" coil. If a generator is operated with the generator switch turned to ON, the G relay in the generator control panel will energize and close the contacts between terminals 23 and 33. This will cause a 28-volt DC signal to be impressed at terminal 33 through the external power disarm relay, to the external power breaker trip coil, disconnecting the external power from the central tie bus.

When the main EXT POWER switch is turned to OFF, 28 volts DC is applied directly to the trip coil of the external power breaker, disconnecting external power from the central bus. External power is protected by a differential protection system. This system protects the three-phase AC power system from line-to-ground, line-to-line, and three-phase faults.

A typical AC power distribution system is so designed that it is possible to operate any load from external power, from the engine generators, or from all of the generators paralleled together. The following are possible conditions:

a. External power to the complete aircraft. This is achieved by closing the external power circuit breaker and the bus tie circuit breaker.

b. External power to any load. To do this, close the external power circuit breaker and the bus tie circuit breaker to the load bus on which you desire power.

c. Each generator supplying its respective load. Close the generator circuit breakers and leave the bus tie circuit open.

d. One generator supplying power for the entire aircraft. Close the generator circuit breaker for the operating engine and close all of the bus-tie circuit breakers.

e. All generators operating in parallel. Close all of the bus-tie circuit breakers. Then, move the paralleling selector switch to the generator that you desire on the synchronizing bus. This closes the respective generator circuit breaker. Follow this procedure through the three generators. Then, all generators are paralleled automatically through the paralleling unit.

f. Various combinations of two generators paralleled and one running in isolation. Close any two of the bus-tie circuit breakers. Move the paralleling selector switch to those selected. This will parallel those two, leaving the third in isolation.

Whenever you troubleshoot the external power system or any electrical system, make sure you use the correct TO. Use the proper wiring diagram and a schematic like figure 5-1. This will save you time and effort. If you could not get external power on the aircraft, the first thing you might check out is the control circuit breaker. If the breaker was pulled out, all you would do is reset it. Often, just looking at the schematic will save you a lot of time.

Load bank operation. Provisions have been made in the external power system to utilize the external power receptacle for connecting a load bank to the aircraft bus.

When a type A–1 load bank is connected to the external power receptacle, the external power disarm relay circuit is energized by 28 volts DC from the external power control circuit breaker. This connection is made through the relay coil (disarm relay) to pin f (see Fig. 5-1) of the external power receptacle, which is grounded at the load bank. This provides a circuit from the main EXT POWER switch on the AC control panel, through a set of contacts on the now energized external power disarm relay, and on through the external power lockout relay to the "close" coil of the external power breaker. When the external power disarm relay is energized, the power circuit to the interlock relay opens. When the interlock relay is deenergized, its contacts, in series with the generator breaker, close. This allows the generator breakers to close, thus connecting the load bank to any one or all of the generators through these breakers. External power can be isolated to the central tie bus by pushing the BUS TIE ISOLATE switch. Pushing the BUS TIE ISOLATE switch trips all bus tie breakers.

Along with operating the load bank, you also must maintain the external power system wiring and components. Inspect the system in accordance with tech data. Bench checks and repair of components are limited, most of the parts are remove-and-replace type of items. Usually you install a component in the reverse order that you remove it. If you are changing a phase sequence relay, make sure that power is not applied to the system while you are working on it, or you could have a shocking experience.

Exercises (242):

1. The external power receptacle (shown in fig. 5-1) provides for what connections?

2. When is the external power lockout relay energized?

3. What relay in the external power system will prevent AC power with the wrong phase sequence being connected to the aircraft bus?

4. How is the disarm relay circuit completed during load bank operation?

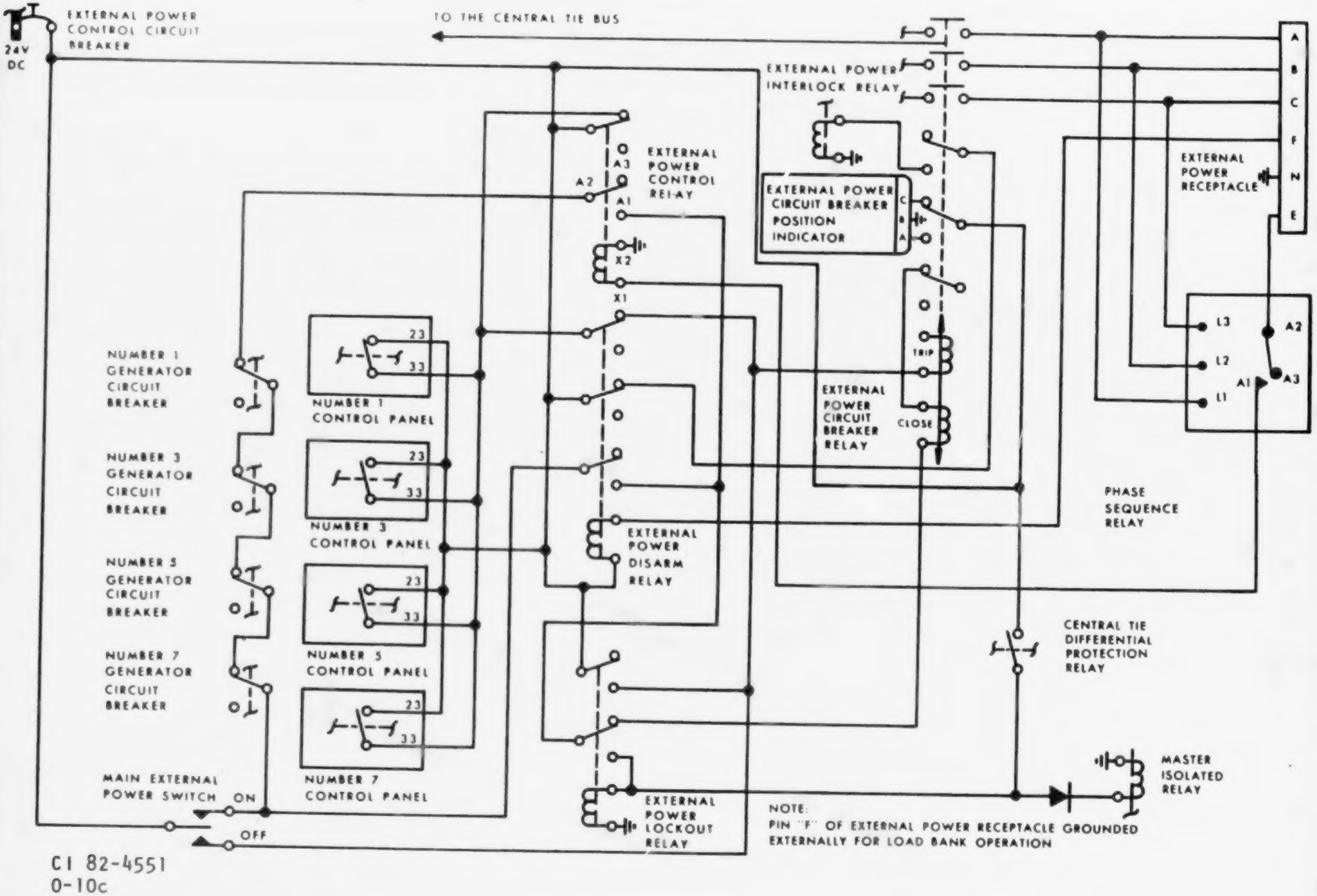

EXTERNAL POWER CONTROL CIRCUIT BREAKER
24V DC
TO THE CENTRAL TIE BUS
EXTERNAL POWER INTERLOCK RELAY
A
B
C
F
N
E
EXTERNAL POWER RECEPTACLE
EXTERNAL POWER CONTROL RELAY
A3
A2
A1
X2
X1
EXTERNAL POWER CIRCUIT BREAKER POSITION INDICATOR
C
B
A
TRIP
CLOSE
EXTERNAL POWER CIRCUIT BREAKER RELAY
L3
L2
L1
A2
A1
A3
PHASE SEQUENCE RELAY
NUMBER 1 GENERATOR CIRCUIT BREAKER
NUMBER 3 GENERATOR CIRCUIT BREAKER
NUMBER 5 GENERATOR CIRCUIT BREAKER
NUMBER 7 GENERATOR CIRCUIT BREAKER
23
33
NUMBER 1 CONTROL PANEL
NUMBER 3 CONTROL PANEL
NUMBER 5 CONTROL PANEL
NUMBER 7 CONTROL PANEL
EXTERNAL POWER DISARM RELAY
CENTRAL TIE DIFFERENTIAL PROTECTION RELAY
MASTER ISOLATED RELAY
MAIN EXTERNAL POWER SWITCH
ON
OFF
EXTERNAL POWER LOCKOUT RELAY
NOTE:
PIN "F" OF EXTERNAL POWER RECEPTACLE GROUNDED EXTERNALLY FOR LOAD BANK OPERATION
CI 82-4551
0-10c

Figure 5–1. External power system.

5-2. Transformer-Rectifier Systems

The continuing trend toward the use of alternating current as the primary source of electrical power on many aircraft has necessitated the use of transformer-rectifier (T-R) units as the primary source of direct-current power. This means that you, the aircraft electrician, must know the principles of operation of the various types of T-R units, including the special-purpose types used in aircraft battery charging systems. You must be completely familiar with the effects that a varying load has on each type of T-R unit so that you can successfully troubleshoot malfunctions and maintain T-R systems.

A transformer-rectifier is a device that changes alternating current into direct current. All T-R units consists of a transformer section that reduces the input AC voltage and some means of changing AC into DC. You may consider that there are three types of T-R units: the dry-disc rectifier type, the static type, and the special purpose type. Since the rectifier type is probably the most widely used, we will discuss it first.

243. Cite operational characteristics of three types of transformer-rectifiers.

Types. There are three basic types of T-R units, they are (1) rectifier-type T-R unit, (2) static-type T-R unit, and (3) special purpose T-R unit. We will start by discussing the most widely used T-R unit; i.e., the rectifier-type T-R unit.

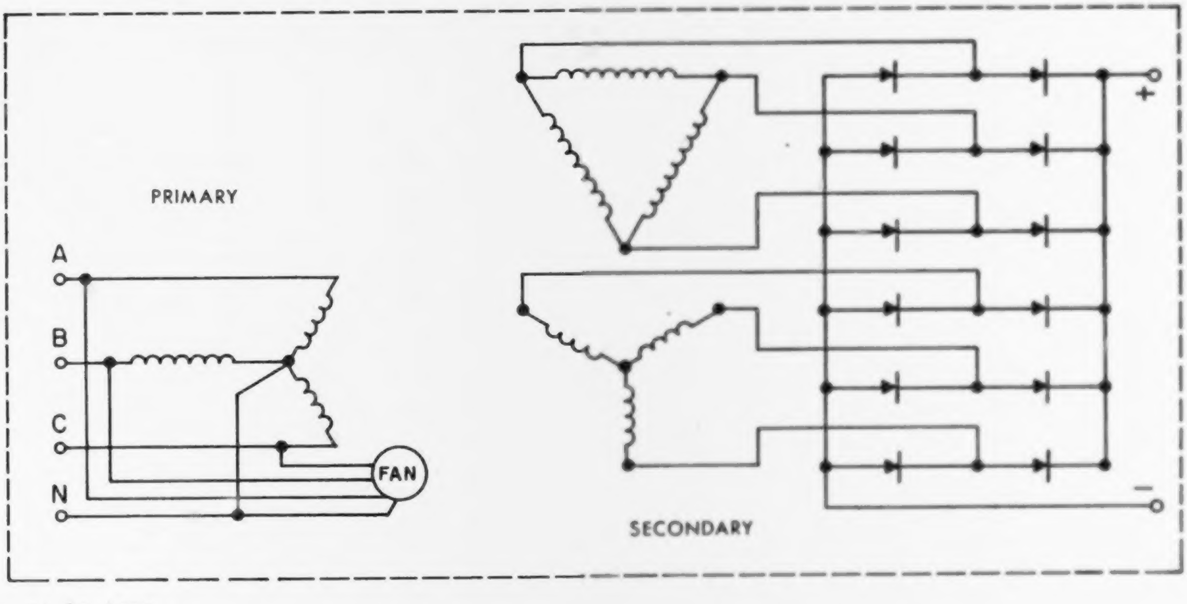
Rectifier-type R-T unit. The rectifier type T-R unit consists of a transformer, a bank of dry-disc rectifiers, and a cooling fan. A schematic of this unit is shown in figure 5-2.

The transformer consists of a wye-wound primary winding and two secondary windings (a wye winding and a delta winding). The three-phase AC input is applied through terminals A, B, and C where it is stepped down. The output across the wye-delta secondary is applied to the bank of dry-disc rectifiers and the DC output is furnished to the distribution system from the terminals marked + and −. The T-R unit shown in figure 5-2 operates from a 200-volt, three-phase, 400-Hz AC system; and the output is rated at 24 volts and 100 amperes. Some aircraft DC power systems require T-R units with only a 50-ampere output. A 50-ampere T-R unit is almost the same as the 100-ampere unit, except that a delta connected secondary is used with the 50-ampere unit and a wye-delta connected secondary is used with the 100-ampere unit.

The cooling fan receives it input AC from the main power source. The purpose of the fan is to draw air across the bank of rectifiers. Proper operation of the fan motor is very critical on dry-disc T-R's. If the fan motor should fail while the T-R was operating under a load, the unit would tend to overheat and fail within a short period of time; and the load on the distribution system at that time would have to be divided among any remaining T-R units in the system.

A typical T-R unit is labelled with an arrow that indicates the power direction of airflow through the unit. Air is always exhausted at the terminal end. In installations, it is important that all the T-R units exhaust in the same direction; if one should be exhausting in an opposite direction, the other T-R's would tend to draw in hot exhaust air. This air would raise their operating temperatures. On many aircraft, proper operation of the cooling fans is an item of inspection by the aircrew during their preflight inspection.

Static-type T-R unit. The static-type T-R unit can be found on many later model craft, and it serves the same purpose as the more conventional T-R unit discussed



CI 82-4552
0-10c

Figure 5–2. Rectifier-type T-R unit.

previously. It delivers 24 volts DC at either 100 amperes or, in some cases, 200 amperes. It operates on a different principle, however, as you can see by examining the schematic diagram shown in figure 5-3.

The transformer section consists of two separate transformers; one transformer has a wye-connected primary and a three-wye secondary, and the other transformer has a delta-connected primary and a three-wye secondary. Both primaries are connected in parallel to the 200-volt, three-phase, 400-Hz AC input. The turns-ratio of the two secondaries are so adjusted that the output voltages are the same and can be paralleled together. The common connection of the AC portion of each secondary winding is interconnected through an interphase transformer that suppresses drift current between the secondaries, bleeding them off through the coils center-tapped to the negative terminal. The low-loss silicon diodes provide the necessary rectification. Due to the use of the silicon diodes, these T-R units need no cooling other than that furnished by convection. The DC output is furnished through the terminals marked + and −.

Special purpose T-R unit. To maintain the state of charge of a nickel-cadmium battery, it is necessary to provide a more closely controlled source of battery-charging power than that provided by a conventional battery-charging rectifier. For this reason, many aircraft in which nickel-cadmium batteries are installed use a special type of T-R unit known as a battery-charging T-R unit. A schematic diagram of a typical battery-charging T-R unit is shown in figure 5-4. It is rated at 28.5 volts DC at 25 amperes.

The three-phase AC input from the primary AC-power source is applied through a three-phase stepdown transformer, and the output is applied to six silicon-power rectifiers in a six-phase half-wave arrangement. This arrangement is more efficient than a full-wave connection, since the load current does not have to flow through two rectifiers in series. By this method heating and the need for voltage regulation are reduced, because there is less voltage drop across the rectifiers. Although the voltage-regulating requirements are somewhat reduced, some regulation is required so that the output voltage of the T-R unit rises as the load current is increased. To obtain this characteristic, a self-saturating, variable reset component or core (MA1) is

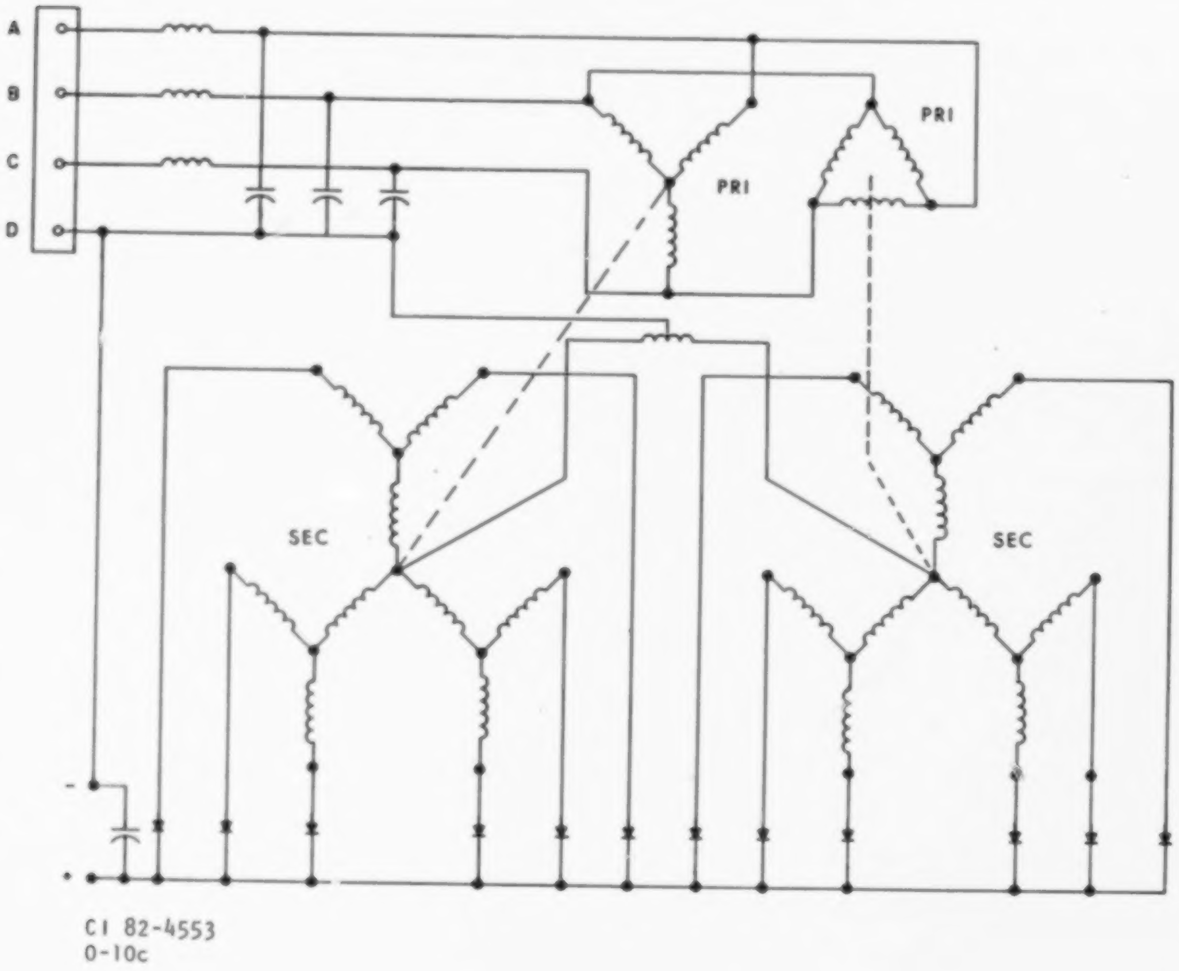


Figure 5-3. Static-type T-R unit.

placed in series with the center tap of each transformer winding. Each core regulates the output of a pair of rectifiers. With this arrangement only three regulating cores are required for the six rectifiers (three pairs), and the control circuitry is reduced to a minimum, as shown in figure 5-4.

The required voltage regulation is provided by a voltage-sensing network. The sensing network consists of resistor R4, reference voltage diode CR7, and the parallel combination of R6 and RT1. The output of this sensing circuit is applied to coil winding CW2 on the regulating core (MA1). A load-change signal is provided by CW1, which is in series with the load. The function of CW1 is to minimize circulating currents caused by voltage induced in the winding (CW2) when the reactors are absorbing a voltage change.

The rectified current pulse flowing through winding CW1 will saturate the reactor core.

The function of the control circuit current is to reset (bias) the cores after each current pulse so that the cores can absorb a voltage change from the next current pulse during the time the flux in the core is driven from the reset (biased) value to saturation. In other words, during a current pulse, the control circuit must determine pulse magnitude and duration or how long the regulating elements will be turned on.

When the battery is low, the control circuit will cause the regulating elements to conduct for a longer period of time and the magnitude of the pulse will be greater than that for a battery that is at or near a full charge.

A thermistor circuit, consisting of RT1 and R6, is used in the circuit to compensate for the heat generated by the load that would affect the operating characteristics of the unit. RT1 has a negative temperature coefficient and R6 has a positive temperature coefficient. Any changes in temperature that would affect the resistance of the output circuit will therefore be canceled out.

In your work as an aircraft electrical repairman, you will encounter a wide variety of T-R power distribution systems. The systems vary both in type of unit or units used and in the output ratings; for example, you have already seen that the rating of T-R units varies from 25 to 100 amperes. Some of the newest aircraft use T-R units having a 200-ampere capacity. Nevertheless, the operating principles remain the same as for those units we have already discussed.

Maintenance. The maintenance you can perform on a T-R unit is generally limited to the repair or replacement of sub units of the major assemblies. You may disassemble a T-R unit only to the extent authorized by your shop; for example, you can completely disassemble a rectifier type T-R unit and repair or replace any of the major assemblies. When you disassemble the battery-charging T-R unit, however, you are not allowed to open the transformer section. Another important point should be brought out at this time. Many components of the static T-R's and battery charging T-R's come in matched sets. If one part of a set requires replacement, you will have to install a whole new matched set. This is why it is important to consult the appropriate technical directive before you attempt to repair or replace any part of a T-R unit.

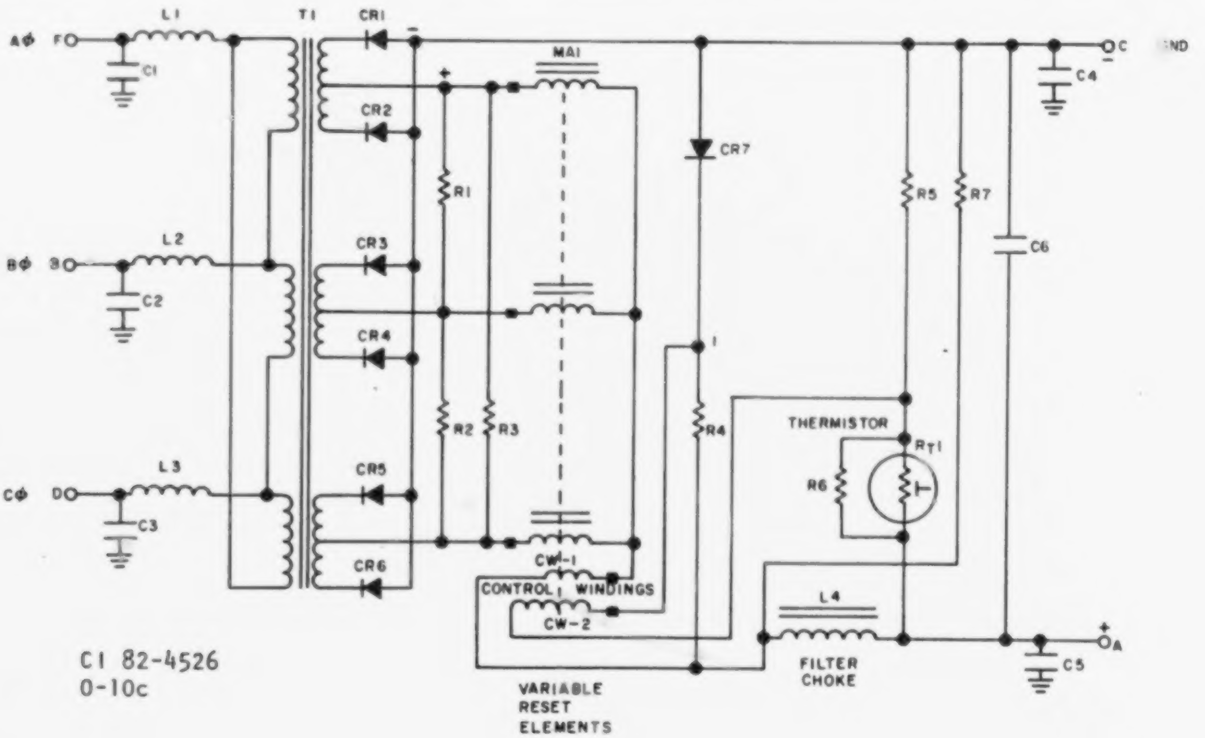


Figure 5-4. Battery-charging T-R unit.

Exercises (243):

1. What is the difference between a 50-ampere output rectifier-type T-R unit and one rated at 100 amperes?

2. a. During operation of the rectifier-type T-R unit, what does its cooling fan draw air across?

   b. Failure of the fan, when the unit is under load, would do what to the load on distribution system?

3. How is the static T-R unit cooled?

4. In the battery-charging T-R unit, what happens to the output voltage when the load is increased?

5. Generally, how much maintenance can be done to the T-R unit?

5-3. Battery System

The battery system on most aircraft is designed primarily to be used as an emergency power source. This system must be maintained in top condition at all times. The design and operation of battery systems will, of course, differ for various type of aircraft, but they all must work properly when needed. We will discuss a typical cargo plane battery system.

244. State operating characteristics of a battery system.

Battery System. Refer to figure 5-5 as we go through the operation of the battery system. The battery system provides a means of operating certain essential DC equipment when external power or power from the transformer-rectifier system is not available. The system is controlled by a DC external power and battery switch located on the overhead electrical control panel. The three positions of this switch are EXT DC PWR, BATTERY, and OFF. The battery system consists of a 24-volt battery located in the battery compartment; a battery relay and a reverse current relay located on the pilot's side distribution panel, and an isolated DC bus OFF indicator light. A bus tie switch on the overhead electrical control panel operates the reverse current relay through a touchdown auxiliary relay on the aft cargo equipment rack.

Battery. One 24-volt 31 (at one hour rate) or 36 (at a five hour discharge rate) ampere-hour battery is installed in a recessed compartment on the lower-left side of the nose section. The battery is easily reached through a hinged door on the compartment. A battery bus on the pilot's side distribution panel is connected directly to the battery. Battery power is supplied also to an isolated DC bus when the battery switch on the overhead electrical control panel is in BATTERY position. An overflow duct on the battery is connected by rubber tubing to a sump jar located aft and below the battery. Battery-gas vent lines are provided from the battery and sump jar to conduct explosive gases overboard through an opening in the fuselage skin. The battery is supplied with a quick-disconnect plug and is mounted on a sliding tray to aid in handling.

Battery Relay. You can see in figure 5-5 that the battery relay is in the pilot's side distribution panel. This relay connects the battery bus and the isolated DC bus when the relay is energized. The relay is energized by power from the battery bus when a ground is applied by placing the battery switch in the BATTERY position.

When the relay is energized, 24-volt, DC power from the battery is applied through the battery bus and closed contacts of the relay to the isolated DC bus. A reverse current relay permits current flow from the isolated DC bus to the essential DC bus while the airplane is on the ground and the bus tie switch points toward the essential bus. The battery relay requires a minimum of 16 volts to energize.

Reverse Current Relay. A reverse current relay connecting the essential DC bus and the isolated DC bus is located on the pilot's side distribution panel. This relay permits current flow from the essential DC bus to the isolated DC bus and prevents the battery from feeding the essential bus while the airplane is in flight. Power from the isolated DC bus is applied to an APP terminal of the relay while the airplane is grounded and the bus tie switch is closed. DC power from a bus tie switch control circuit breaker on the pilot's side circuit breaker panel is routed through the bus tie switch and the contacts of a touchdown auxiliary relay to the APP terminal. This terminal on the reverse current relay applies power directly to a main contactor coil C in the relay. The essential and isolated DC buses are thus connected through contacts of the energized relay.

You can see from the operation of these system components that the battery can supply power to other than emergency circuits. When this is done, however, the capacity of the battery is reduced. During flight, the battery switch is kept in the BATTERY position. This permits the battery to be charged by the constant potential method from the essential DC bus. The isolated DC bus OFF indicator light indicates when the isolated bus is powered only by the battery.

Troubleshoot and Inspect. Whenever you are called on to troubleshoot the battery system, make sure you use the proper aircraft wiring diagram. The schematic like the one shown in figure 5-5 can also help you. If you receive a job that said the battery would not power the essential bus on the ground, where would you start troubleshooting first? A quick look at the schematic should tell you to check the touchdown relay circuit breaker and the bus tie switch

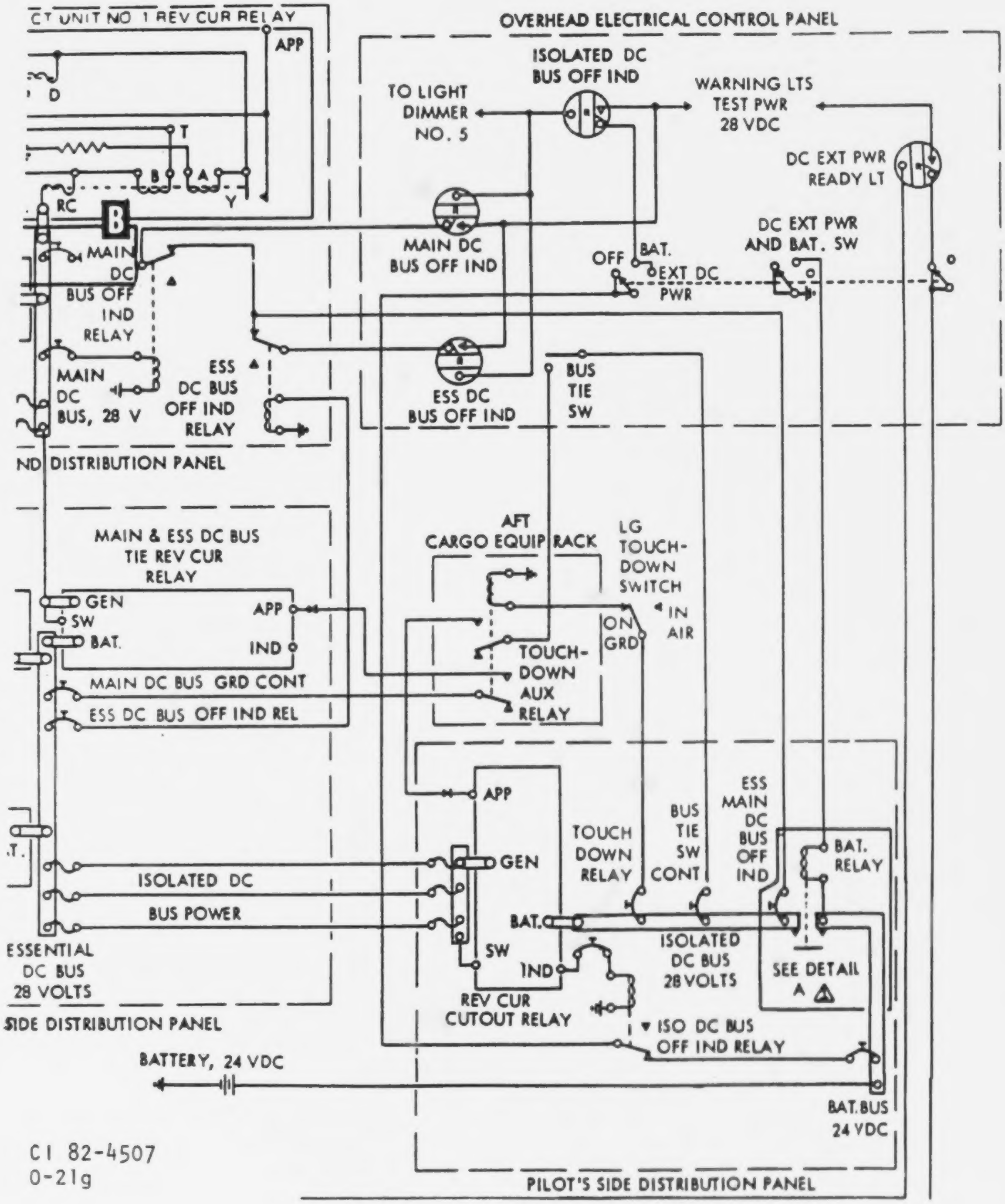

CT UNIT NO 1 REV CUR RELAY
APP
D
T
B
A
Y
RC
B
MAIN DC BUS OFF IND RELAY
MAIN DC BUS, 28 V
ESS DC BUS OFF IND RELAY
ND DISTRIBUTION PANEL
OVERHEAD ELECTRICAL CONTROL PANEL
ISOLATED DC BUS OFF IND
TO LIGHT DIMMER NO. 5
WARNING LTS TEST PWR 28 VDC
DC EXT PWR READY LT
MAIN DC BUS OFF IND
DC EXT PWR AND BAT. SW
OFF
BAT.
EXT DC PWR
ESS DC BUS OFF IND
BUS TIE SW
MAIN & ESS DC BUS TIE REV CUR RELAY
GEN
SW
BAT.
APP
IND
MAIN DC BUS GRD CONT
ESS DC BUS OFF IND REL
AFT CARGO EQUIP RACK
LG TOUCH-DOWN SWITCH
IN AIR
ON
GRD
TOUCH-DOWN AUX RELAY
APP
GEN
BAT.
SW
IND
TOUCH DOWN RELAY
BUS TIE SW CONT
ESS MAIN DC BUS OFF IND
BAT. RELAY
ISOLATED DC BUS 28 VOLTS
SEE DETAIL A
.T.
ISOLATED DC BUS POWER
ESSENTIAL DC BUS 28 VOLTS
SIDE DISTRIBUTION PANEL
REV CUR CUTOUT RELAY
ISO DC BUS OFF IND RELAY
BATTERY, 24 VDC
BAT. BUS 24 VDC
PILOT'S SIDE DISTRIBUTION PANEL

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Figure 5–5. Battery system.

control circuit breaker. If this quick visual inspection looked all right, then you would probably go to the reverse current relay for your voltage checks.

Inspection of the battery system is like other aircraft inspections. They are used to find and correct potential problem areas. Always use the right checklist and aircraft technical data when you inspect the battery system. One thing you should look for is corrosion around the battery due to acid fumes.

Exercises (244):

1. What is the main purpose of the battery system?

2. What is the battery relay used for?

3. What is the minimum voltage required to energize the battery relay?

4. On the ground, which terminal of the reverse current relay must be powered to connect the essential and isolated DC buses?

5-4. Motors

Up to this point we have discussed means of generating electrical energy. Now it is time to use this energy. Electrical energy can be transformed into mechanical energy to raise and lower the landing gear, the flaps, and even the pilot's seat.

A motor, either AC or DC, is a rotating machine which transforms electrical energy into mechanical energy. A motor, like a generator, consists of two principle parts—a field assembly and an armature assembly. The armature is the rotating part in which current-carrying conductors are embedded. These conductors are acted upon by magnetic fields, which cause them to move and make the armature rotate. The magnetic fields are the fields surrounding either permanent magnets or electromagnets; however, electromagnets are used almost exclusively. In this section, we will limit our discussion to the operational fundamentals of DC and AC motors.

245. Differentiate between three types of DC motors.

DC Motors. A motor operates by a force that is exerted on a current-carrying conductor placed in a magnetic field. The tendency of this force to cause rotation is called *torque*. Figure 5-6, part A, shows the forces acting on a single-turn coil conductor in a magnetic field. Current flowing out of the left-hand conductor and into the right-hand conductor establishes magnetic fields around the conductors, as shown. This causes a distortion of the magnetic flux. The lines of force from the pole pieces are strengthened below the right-hand and above the left-hand conductors. Likewise, those above the right-hand and below the left-hand conductors are weakened. As the result of the reaction between the magnetic fields, the right-hand conductor tends to move upward, while the left-hand conductor tends to move down. This rotation continues until the conductors reach the position indicated in figure 5-6, part B. In this position, the forces tend to spread the conductors apart and there is no further torque tendency to rotate the coil.

The problem in the single-coil DC motor is to cause the armature to rotate past the position where the conductors are supposed to move parallel to the magnetic flux of the pole pieces (fig. 5-6,B). We depend on momentum or inertia to move the coil past this position. Then, to keep the coil moving in the same direction, we use a commutator which reverses the direction of electron flow each time the conductor reaches the *no-torque* position. In the DC generator, the commutator changes AC in the conductors to DC in the output. The process is reversed in the motor; the DC input is changed to AC in the conductors.

A single-coil motor, even with a commutator, is impractical because of the pulsating torque. A large number of properly spaced coils on the armature will provide a torque that is both steady and strong, regardless of armature position. The construction of a motor armature is the same as that of a generator armature. Additional pairs of poles, as in a generator, are also used. The rotational force (torque) that turns the motor armature depends on two factors—armature current and the strength of the magnetic field. Increasing either of these increases torque.

When the armature in a motor rotates in a magnetic field, a voltage is induced in its windings. This voltage is called the back- or counter-electromotive force (CEMF) and is opposite in direction to the voltage applied to the motor from the external source. CEMF opposes the voltage that creates the current that rotates the armature. Figure 5-7 depicts the voltages present in an operating motor. By application of the left-hand generator rule, you can see that the CEMF opposes the applied voltage. Since there must be motion to generate a voltage in the armature winding, CEMF is not present until the armature assembly starts turning. The current flowing through the armature decreases as the CEMF increases. The faster the armature rotates, the greater the CEMF.

For this reason, a motor will draw a fairly high current when starting, but as the armature speed increases, the CEMF generated increases and the current flowing through the armature decreases. At rated speed, the CEMF may be only a few volts less than the applied voltage. With this explanation, you can see why the current draw of a motor cannot be determined by the ohmic resistance of the armature. You may find a 28-volt motor with an armature resistance of 0.1 ohm operating on 40 amperes. According to Ohm's law, this motor should draw 280 amperes. However, with the motor in operation, there is a 24-volt CEMF developed in the armature. With 28 volts applied and a 24-volt CEMF, the effective voltage in the armature is only 4 volts. Then, according to Ohm's law, the current

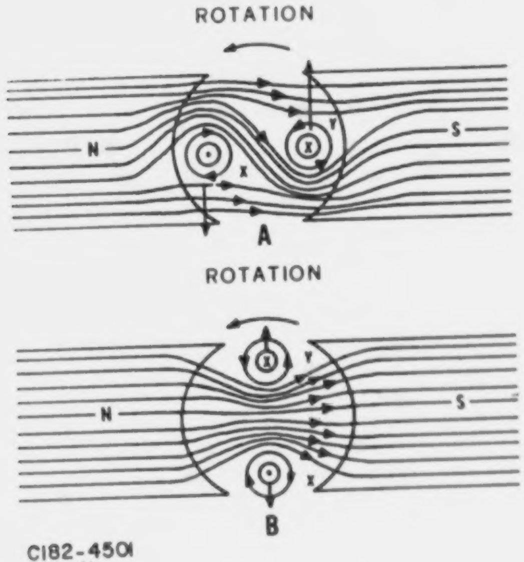

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Figure 5-6. DC motor principles.

flow is only 40 amperes.

As a load is added to a motor, the armature speed decreases. When this happens, the CEMF decreases, causing an increase in the armature current which will increase the output torque.

There are three basic types of DC motors—series motors, shunt motors, and compound motors. They differ in the way their field and armature coils are connected.

Series motor. In the series motor, the field windings, consisting of a relatively few turns of heavy wire, are connected in series with the armature winding, as shown in part A of figure 5-8. The same current that flows through the field winding also flows through the armature winding. Any increase in current, therefore, strenghens the magnetism of the field.

Because of the low resistance in the windings, the series motor is able to draw a large current when starting. This starting current, in passing through both the field and armature windings, produces a high-starting torque which gives the series motor its principal advantage—high-starting torque. This makes the series motor ideal for starter or actuator functions.

The speed of a series motor depends on the load. Any change in load is accompanied by a substantial change in speed. A series motor will run at high speed when it has a light load and at low speed with a heavy load. If the load is removed entirely, the motor may operate at such a high speed that the armature will fly apart. For this reason, a series motor is normally bench tested under no-load condition, at half the rated voltage.

Shunt motor. In the shunt motor, the field winding is connected across the power supply line, i.e., in parallel with the armature, as shown in part B of figure 5-8. The resistance in the field winding is high. Since the field winding is connected directly across the power supply, the current through the field is constant. The field current does not vary with motor speed as it does in the series motor, and therefore, the torque of the shunt motor will vary only with the current through the armature. The torque developed at starting is less than that developed by a series motor of equal size.

The speed of the shunt motor varies very little with changes in load. Suppose the load on a shunt motor increased. The immediate effect of this is to reduce armature speed. Slowing down the armature reduces the CEMF, producing an increase in the amount of armature current flowing. This has the effect of increasing torque to bring the armature speed right back up. The reverse happens when the load on a shunt motor is decreased. This motor is particularly suitable for use when constant speed is desired and when high-starting torque is not needed.

Compound motor. Like the compound generator, the compound motor has both series and shunt field windings, as shown in part C of figure 5-8. The series winding may either aid the shunt winding (cumulative compound) or oppose the shunt winding (differential compound). The differential compound motor is not used by the Air Force.

The characteristics of the cumulative-compound motor lie somewhere between those of the series and those of the shunt motor. As the load is increased, the increase in current increases the flux due to the series winding. This increases the torque faster than the increase for a straight shunt motor. But this increase in flux decreases the speed more rapidly than the speed decrease in a shunt motor. The applied and developed torques are balanced with less speed decrease than in a series motor, but more than in a shunt motor, as shown in figure 5-9.

Because of the series field, the cumulative-compound motor has a higher starting torque than a shunt motor. Cumulative-compound motors are used in driving machines that are subject to sudden changes in load. They are also used where a high-starting torque is desired, but a series motor cannot be used.

The direction of rotation of a motor may be reversed by reversing the direction of current flow in either the armature or the field windings, but not in both at the same time. This will reverse the magnetism of either the armature or the magnetic field in which the armature rotates. If the wires which connect the motor to an external source are reversed, the direction of rotation will not be reversed, since changing these wires reverses the magnetism of both field and armature and leaves the torque in the same direction as before.

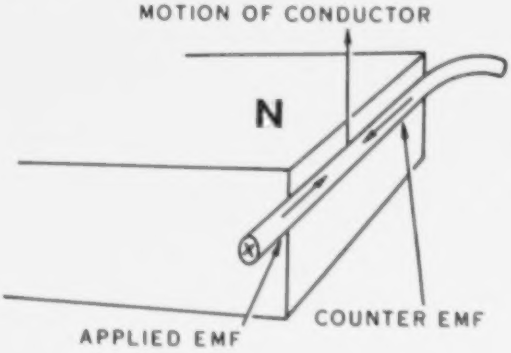

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Figure 5-7. Voltages in a motor armature.

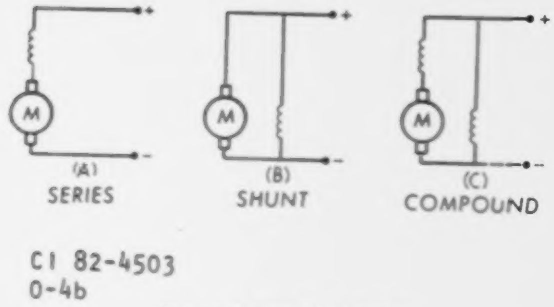

Figure 5-8. Types of DC motors.

Exercises (245):

1. What are the factors that control torque?

2. Explain the presence of CEMF in a DC motor.

3. Explain the internal connections in a series motor.

4. a. On a shunt motor, how are the field and armature windings connected in respect to the power supply?

   b. Explain how this motor regains its speed when an increase in load is placed on it.

5. Why would a cumulative compound be a good motor to drive machines subject to sudden changes in load?

6. How is the direction of rotation reversed in a DC motor?

246. Specify operational characteristics of AC motors.

AC Motors. AC motors have a number of advantages over DC motors. The three main advantages are less arcing at high altitudes, smaller size, and lighter weight for the same power output. There are two general types of AC motors which are used on aircraft, the induction and the synchronous. The induction motors are further divided into three classes: single-phase, two-phase, and three-phase. Of these, the three-phase is the class generally found on aircraft.

Induction motors. The induction motor has long been known for dependable, troublefree service. This type of motor is used where small and medium-sized AC motors are needed. The speed is determined by the number of poles and the frequency of the supply voltage and remains constant over a wide range of loads. The induction motor, as the name implies, operates on the same principles as a transformer, with the stator acting as the primary winding and the rotor acting as the secondary. There are no connections between the stator and the rotor; all voltages in the rotor are created solely by mutual induction. There are three types of rotors found in induction motors.

Squirrel cage rotor. Some induction motors have a rotor that is called a *squirrel cage*. The basic construction principles of all squirrel cage rotors are the same regardless of the differences in appearance (see fig. 5-10). Each is made of a laminated iron core mounted on a spider framework secured to the shaft. Bars (conductors) of copper, aluminum, or some alloy that is a good conductor are laid in slots on the core. The bars (conductors) are welded to end plates at each end of the rotor. That's all there is to it—no electrical connections to outside lines, no insulation, no phases, and no sliprings. This rotor got is nickname from the appearance of the windings when removed from the iron core.

Double squirrel cage rotor. The double squirrel cage rotor contains two sets of rotor conductors. One set of conductors, which has a comparatively small cross-sectional area, is placed in the slots close to the surface of the rotor; the other set, which has a larger cross-sectional area, is placed deeper into the slots. The set with the smaller cross-sectional area has a resistance of a few tenths of an ohm, while the other set has a resistance of a few thousandths of an ohm. The larger number of flux linkages around the larger conductors give this set a greater inductance. The high frequency at which the rotating field cuts both sets of conductors at starting speeds causes the total impedance of the low-resistance conductors to be higher than the impedance of the smaller conductors. In

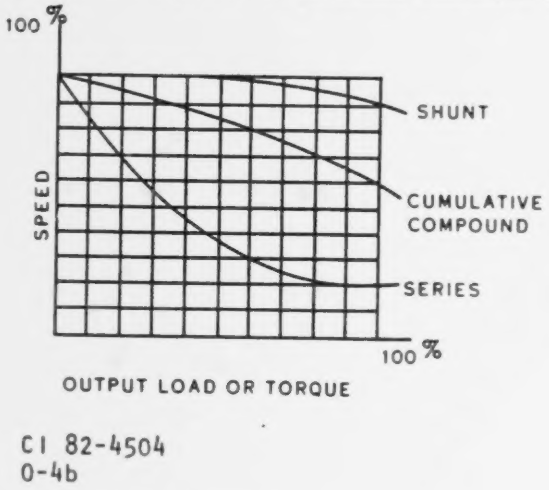

Figure 5-9. Load characteristics of DC motors.

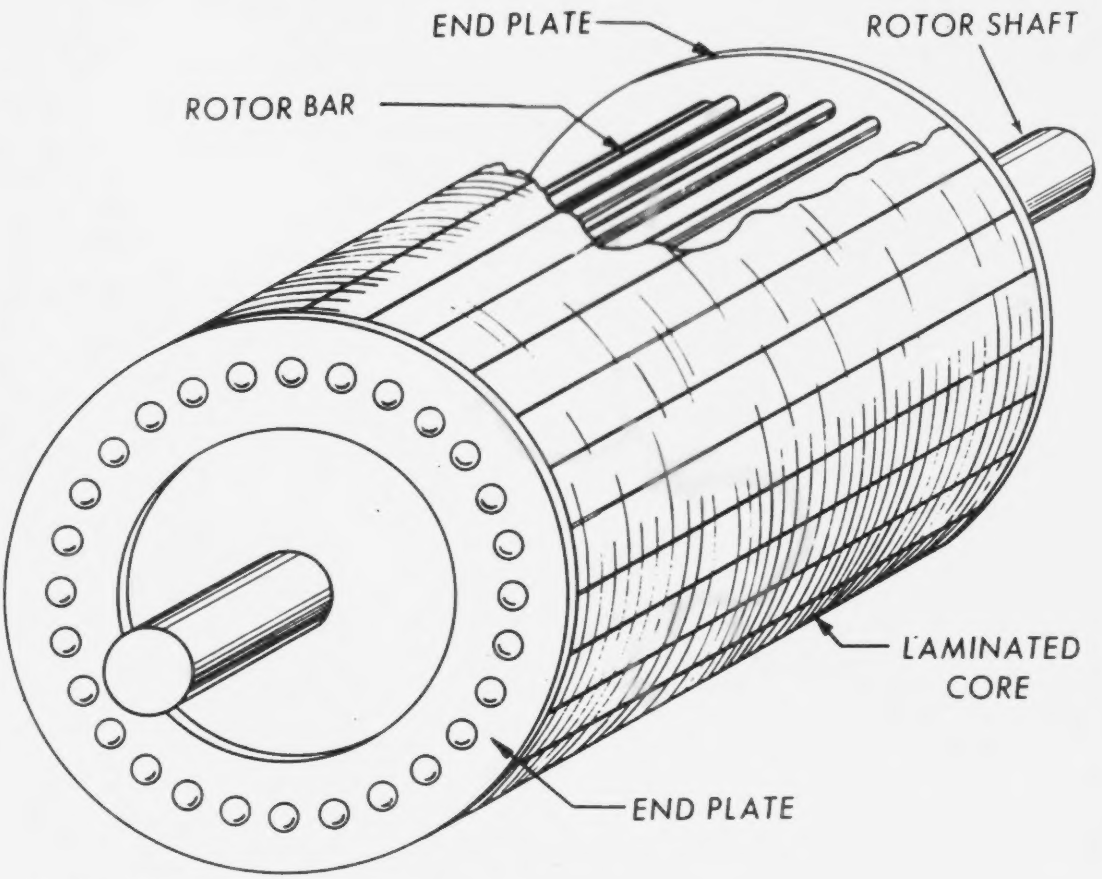

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Figure 5–10. Squirrel cage rotor.

starting, therefore, most of the current flows through the smaller conductors. The higher resistance of these conductors tend to reduce the phase angle between the rotor current and the field flux, and this increases the starting torque. As the rotor comes up to speed, the frequency of the voltage induced in the rotor becomes lower, and the inductive reactance of the larger conductor is reduced. Since the reactance of both sets of conductors is relatively low, the current flow is now limited largely by the ohmic resistance of the conductors. Most of the current now flows through the larger conductors, since they have the lower resistance.

Under no-load conditions, the double squirrel cage motor operates as a normal single squirrel cage motor with most of the current flowing through the larger conductors. Under varying load conditions, the current automatically divides between both sets of conductors in the proper proportions to produce the required amount of torque. The double squirrel cage motor has medium high-starting torque and moderate speed chacteristics. If very high-starting torque and moderate speed control are desired, a wound rotor motor is more suitable.

Wound rotor. These motors, as used by the Air Force, are generally operated on three-phase power. The stator is wound in the same manner as the stator of the three-phase squirrel cage motor; the rotor, however, is wire-wound and is connected into three-phase groups. The leads from one end of the three-phase groups are star-connected, and the other three leads are connected to three sliprings, as shown in figure 5-11. Three rheostats are star-connected through the sliprings to the rotor windings. All three rheostats are mounted on one shaft so that they may all be adjusted simultaneously. The motor is started with the full resistance in the rotor circuit. After the motor starts, the resistance is gradually reduced until it is out of the circuit entirely. The motor is now at full speed. The starting current is not much greater than the full-load current. The wound-rotor motor is a variable-speed motor, since its speed can be controlled by varying the external resistances. Although this type of motor has a higher starting torque than single or double squirrel cage motors, it is not as efficient at running speeds, because it is not possible to have as low a resistance in a wound rotor as in a squirrel cage rotor. This is because the conductors in a squirrel cage rotor have less resistance than the wire in the wound rotor.

An induction motor operates in a manner very similar to

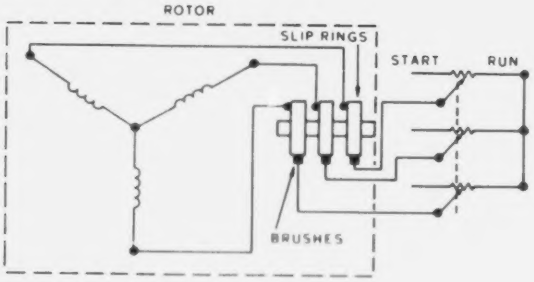

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Figure 5–11. Wound-rotor schematic.

that of the simple induction motor composed of the magnet and disk, except that it is unnecessary to rotate the stator to obtain a rotating field. There are no pole pieces in the stator of an induction motor. Instead, a distributed winding, similar to the stator of a universal motor, is used. The coil groups in the stator are lap-wound, and these groups are connected so as to produce the desired magnetic poles. Any number of poles may be formed by connecting the coils together properly. The stator core remains stationary, but it produces a magnetic field which rotates as if the entire stator were turning. The ability of magnetic fields to add together or cancel out makes it possible to create smoothly rotating field poles. When the motor is running with no load, the rotor will increase its speed to nearly that of the rotating magnetic field. If the rotor speed equaled the speed of the rotating field, there would be no slip; consequently, no voltage would be induced in the rotor windings, and there would be no torque, because the conductors would be cutting no flux lines. Therefore, the rotor would slow down until there was sufficient slip to develop the necessary torque. In a no-load condition, very little torque is required; as stated previously, under no-load conditions the rotor speed nearly equals the speed of the revolving field.

Single-phase motors. When a single-phase winding is excited with a single-phase current, a pulsating field is produced in the stator. The magnetic field changes in all of the poles at exactly the same time and same rate, so no rotating field is produced. A voltage is induced in the rotor (transformer action), but no torque is produced. The motor is merely acting as a transformer—the stator is the primary and the rotor is the secondary. Due to transformer action, the current flowing in the rotor conductors, produces a flux which opposes the flux in the stator, just as the ampere turns of the secondary of a static transformer oppose the primary ampere turns. No torque is developed because of the relative position of the stator and rotor poles. And, there is none during the cycle of current; therefore, no torque is produced by the single-phase motor.

The induction motor does not depend on magnetic induction, it relies on electromagnetic induction. The stator and rotor act like the primary and secondary windings of a transformer. The rotating magnetic field of the stator induces high current in the rotor; and these currents, in turn, produce their own magnetic field, which interacts with the main field to make the rotor turn.

Single-phase induction motors are manually started, unless some system for creating a rotating stator field is employed. The process of deriving two phases from one is known as phase-splitting and is often used to provide a rotating stator field; also the capacitor-start system in conjunction with phase splitting is effective in starting the single-phase induction motor.

Two-phase motors. The two-phase and single-phase induction motors have the same basic construction. However, the coils are not connected together as in the single-phase motor. Since two-phase power has four leads, we simply connect the two leads of each phase to the corresponding phase leads of the power supply.

To change direction of the two-phase motor, simply reverse the connection of either of the two phases. This will reverse polarity in one set of poles and cause the magnetic field and the rotor to rotate in the opposite direction.

On an aircraft, the electrical instruments are about the only units operated by two-phase motors. The majority of AC motors on aircraft are of the three-phase type.

Three-phase motors. The trend of modern aircraft is toward a strictly AC power system. This presents the problem of what type of AC motor should be used in the construction of starter and actuator motors. The three-phase motor, because of its small size and light weight, fits the need perfectly. Also, since the three phases are separated by 120 electrical degrees, there is no need for additional starting devices. The induction principles covered for single-phase motors also apply to three-phase motors.

The direction of rotation of a three-phase motor may be reversed by changing any two of the three power leads. This can easily be done by using a double-pole, double-throw relay connected between two of the three motor leads. This relay is then controlled by a remote switch.

Some of the peculiar characteristics of the three-phase motor are: Even though it will not always start on two phases, it will run on two phases, but will not carry a very large load; the three-phase motor will not self-start on one phase; the three-phase motor has a very high-starting torque and a great power capability.

Synchronous motors. The basic parts of a synchronous motor are the rotor and the stator. The rotor is composed of permanent magnets or is one whose poles are excited by a source of DC and whose polarity does not change. The stator consists of several pairs of poles and is excited by AC. In the synchronous motor, the rotor polarity is established by applying DC through the brushes to the rotor windings. By using a multipole stator as in the three-phase induction motors, we can obtain a rotating field when polyphase AC is applied to the stator. When DC is supplied through sliprings to the rotor windings, a fixed polarity is produced at each pole. These poles lock in step with those of the rotating field, and the rotor is pulled around as the stator magnetic field turns. Because of the lockup, the rotor travels at the same speed as the rotating field. In other words, the rotor speed is synchronized with that of the stator field. It is from this design that the motors derive their name.

Now, lets suppose that the stator and rotor are energized at the same time. According to the laws of magnetism, the stator poles will attract the unlike ones of the rotor. The motor therefore will rotate at synchronous speed.

However, the rotor can't jump from a standstill to synchronous speed in "nothing flat." The windings would be yanked out of their slots and the entire motor would be wrecked. However, if the rotor is brought up to a speed that is the same or nearly equal to that of the rotating field, it will lock in step and be towed around by the field at synchronous speed. How do we bring this condition about? The method is simple. We start synchronous motors as induction types. A squirrel cage winding is placed upon the rotor. When the motor comes up to an rpm that is slightly less than synchronous speed, the DC field on the rotor can be excited and the lockup will occur.

To reverse a synchronous motor, we change direction of current in the rotor or shift the brushes. In either case, we reverse the polarity of the rotor. The synchronous type is used in a few instruments and also electric clocks. But these are about the only devices on aircraft where there is need for such motors.

Exercises (246):

1. Into what three classes are induction motors divided?
2. What determines the speed of an induction motor?
3. What is the advantage of a wire-wound rotor?
4. What type of rotor is used in induction motors?
5. How is a three-phase induction motor reversed?
6. How many phases are necessary for a three-phase motor to run?
7. What is synchronous speed and why are synchronous motors constant speed?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

200 - 1. Neutrons are neutral (no charge) particles and the protons are positive particles in the nucleus. The electrons are the negative particles in orbit around the nucleus.
200 - 2. A normal atom has a neutral charge as the electrons balance the protons.
200 - 3. Heat, chemical, and a changing magnetic field. (Also, any other three given in text.)
200 - 4. Conductor.
200 - 5. Electrical pressure exists when there is a difference in potential between two points. This potential is measured in volts.
200 - 6. Rubber, plastic, and glass are good insulators because they hold their electrons tightly.
200 - 7. Type, size, and temperature of material.
200 - 8. Ohm.
201 - 1. 10 amperes.
201 - 2. 12 volts.
201 - 3. Decreased; decreased.
201 - 4. 20 watts.

202 - 1. 6 amperes.
202 - 2. Total circuit resistance would decrease.
202 - 3. More than one.
202 - 4. Voltage applied.
202 - 5. A series-parallel circuit could be defined as a circuit combining a series circuit and a parallel circuit into one.
202 - 6. 40 ohms.

203 - 1. Magnetism is defined as that property of a material which enables it to attract pieces of iron.
203 - 2. Natural and artificial magnets.
203 - 3. Permanent and temporary.
203 - 4. Reluctance is the opposition a material offers to the magnetic lines of force.
203 - 5. Residual magnetism is the amount of magnetism that remains in a temporary magnet.
203 - 6. Retentivity is the ability of a material to retain residual magnetism.
203 - 7. Permeability is the ease with which magnetic lines of force distribute themselves throughout the material.
203 - 8. Poles of the magnet.
203 - 9. They are encased in a soft iron case called a magnetic screen or shield.
203 - 10. Severe jarring or high temperature.
203 - 11. An electromagnet is an electrically excited magnet capable of exerting mechanical force.
203 - 12. A bar magnet.
203 - 13. An electromagnet.
203 - 14. Saturation is a term used to indicate that the current flowing through a coil is at a point that any further increase will not produce an appreciable increase in lines of flux about the coil.
203 - 15. When you place a bar of iron or soft steel in an energized coil with electron flow through it, the bar is pulled through the coil by the field strength of the coil until the bar's center is near the center of the coil where the field is most intense.

204 - 1. The right-hand motor rule.
204 - 2. The commutator and brushes.
204 - 3. Laws of magnetism.
204 - 4. Increase motor speed or field strength.
204 - 5. Effective electromotive force is the applied voltage minus the induced counter - electromotive force (CEMF).
204 - 6. CEMF.

205 - 1. Current that periodically reverses its direction.
205 - 2. Armature, permanent magnet, sliprings, and brushes.
205 - 3. Hertz.
205 - 4. Peak voltage.

206 - 1. Inductance is a property of a circuit that opposes any change in current flow. Its symbol is L.
206 - 2. Henry; "h".
206 - 3. Voltage; current.
206 - 4. The number of turns in the coil, the diameter of the coil, the coil length, and the type of material used for the core.
206 - 5. Impedance is the total opposition to current flow in an AC circuit; ohm.
206 - 6. Plate area, the distance between the plates, and the type of dielectric.
206 - 7. The farad. However, since the farad is usually too large a unit, microfarads are used most frequently. Its symbol is "(*m" or "MFD."
206 - 8. Zero.
206 - 9. Current leads voltage by 90°.
206 - 10. C.
206 - 11. Fixed and variable.
206 - 12. 600.
206 - 13. High-power circuits with medium high voltage.
206 - 14. In high-frequency circuits subjected to voltages up to 7,500 volts.
206 - 15. Electrolytic capacitors.
206 - 16. Its high-power loss.
206 - 17. Ceramic capacitors.
206 - 18. The time required for a capacitor upto charge to 63 percent of its maximum value.
206 - 19. The time required for the circuit current to equal 63 percent of its maximum value.

207 - 1. The primary.
207 - 2. The secondary.
207 - 3. A core of low-reluctance magnetic material.
207 - 4. An iron-core transformer.
207 - 5. The ratio of the number of turns in the primary to the number of turns in the secondary.
207 - 6. It has a 5 to 1 ratio or a step-down turns ratio.
207 - 7. The extent to which magnetic lines of the primary cut across the secondary.
207 - 8. 90 percent of the lines of flux of the primary winding are cutting the secondary winding.

208 - 1. The rotating magnetic field causes rotor torque and rotation.
208 - 2. Squirrel cage and wound.
208 - 3. *Slip* is the difference between the speed of the stator field and the rotor.
208 - 4. The rotor is compared to a DC motor's armature winding. The stator is compared to a DC motor's field winding.

209 - 1. The parts of a transistor and their jobs are:
(1) Emitter—gives off or emits current carriers (electrons or holes).

(2) Base—controls the flow of the current carriers.
(3) Collector—collects the current carriers.

209 – 2. The classes are NPN and PNP.
209 – 3. An NPN transistor is formed by introducing a thin region of P-type material between two regions of N – type material in a single crystal of germanium or silicon. The PNP transistor is formed by introducing a thin region of N – type material between two regions of P-type material.
209 – 4. The emitter-base junction is forward biased and the collector-base junction is reverse biased.
209 – 5. Some of the electrons recombine with holes and will move out through the base lead in the form of base current (I_B) and return to the emitter supply battery V_{EE}.
209 – 6. In an NPN, the current path is from the negative terminal of the emitter supply battery to the emitter. It will flow through the emitter to the base. From the base, a small portion will return to the positive terminal of the emitter battery. The rest will flow from the base through the collector to the positive terminal of the collector battery as collector current (I_C).
209 – 7. Opposite.

210 – 1. External current flow is always against the arrow.
210 – 2. In a PNP transistor, the arrow points toward the base.
210 – 3. In a NPN transistor, the arrow points away from the base.
210 – 4. The three basic transistor configurations are common emitter, common base, and common collector.
210 – 5. The input is 180° out of phase with the output of a common emitter.
210 – 6. The current gain of a common emitter is high.
210 – 7. It has a low response to high frequencies.
210 – 8. Current flows into the collector and base leads and out of the emitter lead.
210 – 9. An emitter follower.
210 – 10. There is no phase reversal in a common collector between input and output.
210 – 11. The common collector transistor configuration has a high-input impedance and a low-output impedance.

211 – 1. The essential items for a DC-power supply to operate are an AC source and a rectifier.
211 – 2. The simplest rectifier is the half-wave rectifier.
211 – 3. The direction of current flow and location of the grounds in a half-wave rectifier determine whether the DC output is positive or negative.
211 – 4. Filters are used to produce a steady DC output of a half-wave rectifier.
211 – 5. A full-wave rectifier must incorporate at least two diodes.
211 – 6. An important factor to consider when designing a full-wave rectifier for high-voltage output is the peak inverse-voltage rating of the semiconductor diode.

212 – 1. Bias decreases.
212 – 2. The zener diode establishes the emitter voltage on Q2.
212 – 3. Q2 conduction is controlled by the voltage at the arm of R4.

213 – 1. Refer to figure 1-31 to check you answers.

214 – 1. A current decrease in a parallel DC resistive circuit indicates that a resistor in one of the branches has become open. Total circuit resistance has increased causing the drop in current.
214 – 2. The current reading in the branch would be zero.
214 – 3. To prevent shunt or parallel loads from affecting the resistance reading.
214 – 4. Total circuit current would increase greatly.
214 – 5. Current will cease to flow if an open occurs in the series portion of a series – parallel circuit.
214 – 6. Current will increase if a short occurs in a series portion of a series – parallel circuit.
214 – 7. The voltage drop across the series resistor will decrease.
214 – 8. Total resistance of the circuit is decreased.
214 – 9. The voltmeter will read a portion of the applied voltage (the voltage dropped by the series resistor).
214 – 10. The power source must be disconnected from the circuit before connecting an ohmmeter in the circuit.
214 – 11. When an ohmmeter is connected across a shorted component, a reading of zero will be indicated.

CHAPTER 2

215 – 1. 115 VAC and 230 VAC.
215 – 2. In the LOW position.
215 – 3. The four types of probes are unshielded leads, straight coaxial leads, 1:1 probes, and × 10 attenuator probes.
215 – 4. Short unshielded leads.
215 – 5. About 1 megohm paralleled by about 20 pf.
215 – 6. Insert probe into 1 KC CAL connector and obtain 2 or 3 cycles on the display. If the square wave is distorted, unlock the locking sleeve and adjust the probe for a perfect square wave.

216 – 1. Position the switch to AC for signals above 16 Hz and to DC for signals below 16 Hz.
216 – 2. Because an accurate measurement of the peak-to-peak signal cannot be made.
216 – 3. 5 (divisions) × 2 (VOLTS/DIV) × 10 volts peak-to-peak. Peak = 10/2 = 5 volts. RMS = .707 × 5 = 3.54 volts.
216 – 4. 4 (divisions) × 5 (VOLTS/DIV) × 10 (attenuation) = 200 volts. Peak = 200/2 = 100 volts. RMS = .707 × 100 = 70.7 volts.
216 – 5. About 5 divisions.
216 – 6. Set the AC GND DC switch to DC, apply the reference DC to the INPUT connector, and position the trace to the reference line.
216 – 7. The INVERT switch must be pushed in when using Channel 2 to indicate positive polarity above the line and negative polarity below the line.
216 – 8. Instantaneous = 4.1 × + 1 × 2 × 1 = 8.2 VDC.

217 – 1. It simulates closing the squat switch.
217 – 2. Use the aircraft maintenance instructions to turn on the required aircraft power.
217 – 3. The information on the tester panel.

218 – 1. Up to 600 amperes.
218 – 2. Hold it by the handgrip with one hand.
218 – 3. Zero the meter before taking measurements and use the lowest range possible for your reading.

219 – 1. Because it combines the functions of a DC voltmeter, an AC voltmeter, a DC milliammeter, and an ohmmeter.
219 – 2. The carrying handle can hold the instrument at a 30° angle for bench use.
219 – 3. To compensate for variations in battery voltage and internal resistance; i.e., when making resistance measurement.
219 – 4.
  a. The function selector should be set to the 100μA special position.
  b. In series.
  c. The range selector is not used for this μA setting, therefore its position is of no consequence.
219 – 5.
  a. Set the selector switch as DCV 20 KΩ/V.
  b. Set the range selector at 50 volts and, if the reading is less than 10 volts, reset the Range selector to the 10-volt position.
  c. The leads are applied to each end of the resistor. This makes the meter parallel. (NOTE: correct polarity of leads must be attended to.)
219 – 6. Make sure that all power is removed from the circuit being tested.
219 – 7. Be sure to start with a scale or range that will insure against overloading the meter.
219 – 8. Turn the function selector to the OHMS position and zero the meter on each of the resistance ranges.
219 – 9. They will not zero on one or more of the ranges.
219 – 10.
  a. Connect a grounded lead to one of the panel screws of the multimeter to ground the instrument case.
  b. If possible, connect and disconnect the test leads with the power supply off.
  c. If possible, also take the meter reading without touching any part of the multimeter.

220 – 1. To visually check that an AC-voltage source is producing the desired frequency.
220 – 2. The dynamometer has a dial and a pointer that points at a

number which identifies the frequency in Hertz. The reed type has several reeds, and each reed vibrates at a predetermined and marked frequency. If more than one reed is vibrating, the one vibrating the most indicates the nearest correct frequency.

220 – 3. Frequency meters are connected in the same manner as you would use when taking voltage readings.
220 – 4. The storage of a meter or test equipment should be in a place where it will not be subjected to extreme or varying temperatures, dampness, or jarred around.

221 – 1. To measure large values of resistance, such as the resistance of the conductor to insulation breakdown.
221 – 2. Because of the small amount of torque and the lack of balance springs in the movement, the readings are easily affected.

222 – 1. It controls power to the heat block.
222 – 2. Types E–2 and E–4.
222 – 3. Use the HIGH position for initial heating.

223 – 1. The T–31 tester and the A–2 test stand.
223 – 2. The DC generator.
223 – 3. Yes. By authorized modifications.
223 – 4. 115 VAC.

224 – 1. All AC nontransistorized control and protection panels.
224 – 2. Shop tester.
224 – 3. 115 VAC, 60 Hz, single phase.
224 – 4. Troubleshooting portion of the applicable TO.

225 – 1. All control and protection panels.
225 – 2. 115-VAC, 60-Hz, and single-phase.
225 – 3. 400 Hz, and 1600 Hz.
225 – 4. Two. 375 to 420 Hz and 300 to 500 Hz.
225 – 5. Pre-punched punchcards.
225 – 6. Fixed and variable from 0 to 35 volts or from 27 to 63 volts.

226 – 1. Field testing constant-speed transmissions, their 400-Hz components, and certain AC generators.
226 – 2. Approximately 2000 rpm.
226 – 3. The A–1 load bank tester.
226 – 4. In the applicable TO in the troubleshooting section.

227 – 1. Load-testing certain aircraft AC generators.
227 – 2. 250-AMP position.
227 – 3. The power factor meter.

CHAPTER 3

228 – 1. a. The fields are connected in series with the armature.
  b. Through the load.
  c. As the load increases, output voltage increases; and as the load decreases, output voltage decreases.
228 – 2. The field coils are connected in parallel with the armature terminals.
228 – 3. Compound-wound.
228 – 4. The series filed is in series with the load, and the shunt field is in parallel to the load.

229 – 1. Carbon dust particles might adhere to the walls of the slots so that eventually a short circuit would develop between various commutator segments.
229 – 2. None. This is the normal operating color.
229 – 3. Too much pressure causes excessive brush wear and too little pressure results in jumping brushes, poor output, and the possibility of burning the commutator.
229 – 4. A properly seated brush will have a minimum of 100 percent across the thickness and 70 percent contact across the width of the brush.
229 – 5. New brushes can be seated by using a strip of No. 000 or No. 0000 sandpaper the width of the commutator.
229 – 6. The test light will light when connected between the commutator and the armature shaft.
229 – 7. It indicates a short circuit in the armature or the commutator.
229 – 8. The test lamp will light if there is a grounded circuit.
229 – 9. No spark when two adjacent commutator segments are shorted together.

230 – 1. Insure that there is free circulation of air around the regulator. Remove any loose nuts, bolts, or scraps of wire that may be there. Check the regulator shock mounts for evidence of damage.
230 – 2. Current flow through the field coils would increase.
230 – 3. Effective range of regulation is 26 to 30 volts.
230 – 4. It prevents arcing between the discs of the carbon pile.
230 – 5. Any component should be at its normal operating temperature before adjustments are made, because as temperatures change, component's resistance change.
230 – 6. This would cause the temperature to increase. Then the physical resistance would decrease, and the output voltage of the system would tend to rise above its normal level.

231 – 1. When the generator voltage is greater than the battery voltage.
231 – 2. It opens the circuit between the generator and the distribution system.
231 – 3. Sends a trip signal to the field control relay.
231 – 4. From the overvoltage relay.
231 – 5. It effectively disconnects the generator from the distribution system.
231 – 6. Check the components' mounts for damage, check for corrosion and security of electrical connections, and ensure that connecting wires and cables are in good condition.

232 – 1. An ammeter, a generator failure light, and a voltmeter.
232 – 2. To one side of the generator switch, to the voltage regulator, and to the reverse current relay.
232 – 3. a. From a 24-volt battery.
  b. To the FCR, to the OVR, and to the generator switch.
232 – 4. Initial power provides trip power in the event of an overvoltage condition, and it applies a positive DC potential to the generator field.
232 – 5. Field current flow is controlled by the carbon stack of the voltage regulator.
232 – 6. The field control may be reset by the generator switch or manually by a reset button on the relay itself.
232 – 7. The overvoltage relay closes at approximately 32.5 volts.

233 – 1. a. The equalizer circuit.
  b. It operates if there is a difference in potential between D terminal of the generators operating in parallel.
233 – 2. (D) and (K).
233 – 3. You should lower the voltage (a little) of the generator providing the greatest amount of current flow and raise the voltage (a little) of the generator providing the least.

234 – 1. The cockpit voltmeter and ammeter as observed by the pilot or engineer.
234 – 2. Voltmeter wired backwards, generator wired backwards, or reversed polarity of the generator.
234 – 3. By flashing the field.
234 – 4. Defective field circuit.

CHAPTER 4

235 – 1. 60 Hz.
235 – 2. a. A voltage regulator and a constant-speed drive must be used.
  b. Only a voltage regulator is required.
235 – 3. a. A gear train.
  b. By means of a voltage-control circuit.
  c. It must use a resistance-type load.
  d. We should not use inductive or capacitive loads with variable frequency generators.
235 – 4. They provide an even distribution of the field flux.
235 – 5. Only kW (real loads) can be connected to a variable-frequency generator.

236 – 1. a. By means of sliprings and brushes on the rotor.
  b. It maintains a rotating electromagnetic field.
  c. The armature windings are imbedded in the surrounding stator.
236 – 2. a. The permanent magnet generator, the exciter generator, and the main generator.
  b. It is fed into the voltage regulator circuit.

236 – 3. a. By use of 3 capacitors and a diode in the generator's circuitry.
    b. They suppress rectifier peak inverse voltage.
    c. Upon the removal of short circuit currents or upon removal of maximum-load current.

236 – 4. To provide excitation for the exciter field, power to operate the generator, and a source of power for the voltage regulator.

236 – 5. With blast air or engine oil under pressure.

236 – 6. By a constant-speed drive unit.

237 – 1. When the input speed to the drive is greater than the required output speed.

237 – 2. Overdrive. Underdrive.

237 – 3. When the input speed to the drive is less than the required output speed.

237 – 4. When the input speed to the drive is the same as the required output speed.

237 – 5. To control the drive output speed and thereby the generator frequency, and to equalize the load between paralleled generators.

237 – 6. Magnetically, by trim coils soldered to the flyweights.

237 – 7. The limit governor places the drive in full underdrive condition and removes the affected generator from service in case of an underspeed or overspeed condition.

237 – 8. Oil filters, pressure switches, external plumbing, and in some cases, governor assemblies.

237 – 9. A basic field test stand.

237 – 10. You should consult the replacement parts chart of the technical reference for the particular drive unit you are using.

238 – 1. The frequency-and-load controller.

238 – 2: During isolated generator operation, the frequency-and-load controller maintains constant generator frequency. During parallel operation, the frequency – and-load controller performs the additional function of maintaining an equal real – load division between generators.

238 – 3. By a network of current transformers.

238 – 4. To the frequency control on the drive.

238 – 5. It senses the phase angle between the reference frequency and the generator frequency and provides a proportional signal.

238 – 6. The phase "A" voltage of the incoming generator and the phase "A" voltage of the generator(s) on the bus tie.

238 – 7. The generator to be paralleled must be slightly out-of-phase.

238 – 8. A relay in the AUTO parallel unit closes the generator circuit breaker to parallel the machines.

239 – 1. It supplies a signal proportional to the average of the three-line voltages to a DC-control winding.

239 – 2. The resultant value of magnetic flux of the reference signal and the sensing signal.

239 – 3. a. It is a feedback network.
    b. The signal is in such a direction as to oppose any change which occurs due to transient load conditions.

239 – 4. To oppose any change in exciter output voltage due to transient load conditions.

239 – 5. The voltage regulator.

239 – 6. There will be a decreasing system voltage as load is applied to the generator.

240 – 1. The generator control relay.

240 – 2. The lockout relay.

240 – 3. The UNDEREXCITATION relay.

240 – 4. The OVEREXCITATION-UNDEREXCITATION circuit.

240 – 5. The OE–UE loop circuit functions only when the generators are paralleled together.

241 – 1. a. The underspeed switch closes.
    b. The underspeed switch closes—this energizes the underspeed relay, which then sends power to trip the generator breaker relay contacts and remove generator power.

241 – 2. When the generator relay closes, the exciter field circuit is established, control power is connected to the generator breaker switch when the drive is up to SPEED, the generator failure light is turned off, and the relay trip coil circuit is armed.

241 – 3. By placing the generator breaker switch closed, with the auto parallel control relay deenergized, and the external power breaker open.

241 – 4. The bus tie breakers are opened and the generator breakers are closed.

CHAPTER 5

242 – 1. The external power receptacle shown in figure 5-1 provides for connecting external power to an aircraft and for connecting a load bank to the central tie bus.

242 – 2. Any time a central tie bus fault occurs.

242 – 3. The phase sequency relay.

242 – 4. Through pin F of the external power receptacle which is grounded at the load bank.

243 – 1. The transformer in the 50-ampere unit has a delta connected secondary, and the 100-ampere unit has a wye-delta connected secondary.

243 – 2. a. It draws air across the bank of rectifiers.
    b. The load would be divided among any remaining T-R units in the system.

243 – 3. By convection.

243 – 4. The output voltage increases.

243 – 5. Maintenance is generally limited to the repair or replacement of sub-units of the major assemblies.

244 – 1. It is an emergency power source.

244 – 2. It connects the battery bus to the isolated DC bus.

244 – 3. 16 volts.

244 – 4. The APP terminal.

245 – 1. The factors that control torque are the strength of the magnetic field and the armature current.

245 – 2. When the armature in a motor rotates in a magnetic field, a voltage is induced in its windings. The voltage is opposite in direction to the applied voltage.

245 – 3. In a series motor, the field and armature are connected in such a way that the current in the field also flows in the armature.

245 – 4. a. In parallel (shunt).
    b. Slowing down the armature reduces the CEMF, producing an increase in the amount of armature current flowing. This has the effect of increasing torque to bring the armature speed right back up.

245 – 5. The series field provides good starting torque while the shunt field provides the speed control.

245 – 6. By reversing the polarity of either the field or the armature, but not both.

246 – 1. Single-phase, two-phase, and three-phase.

246 – 2. The number of poles and the supply voltage.

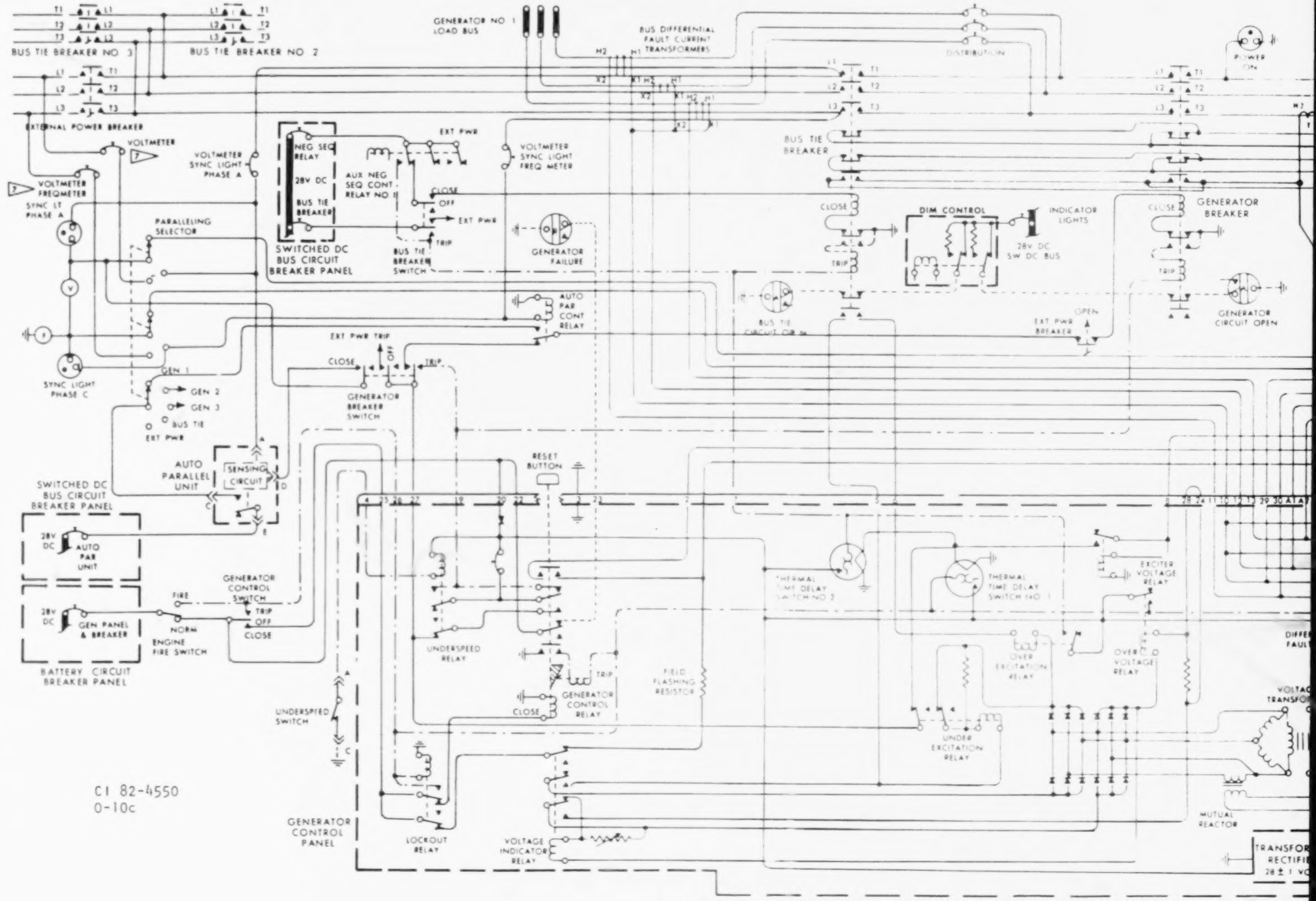
246 – 3. High-starting torque.

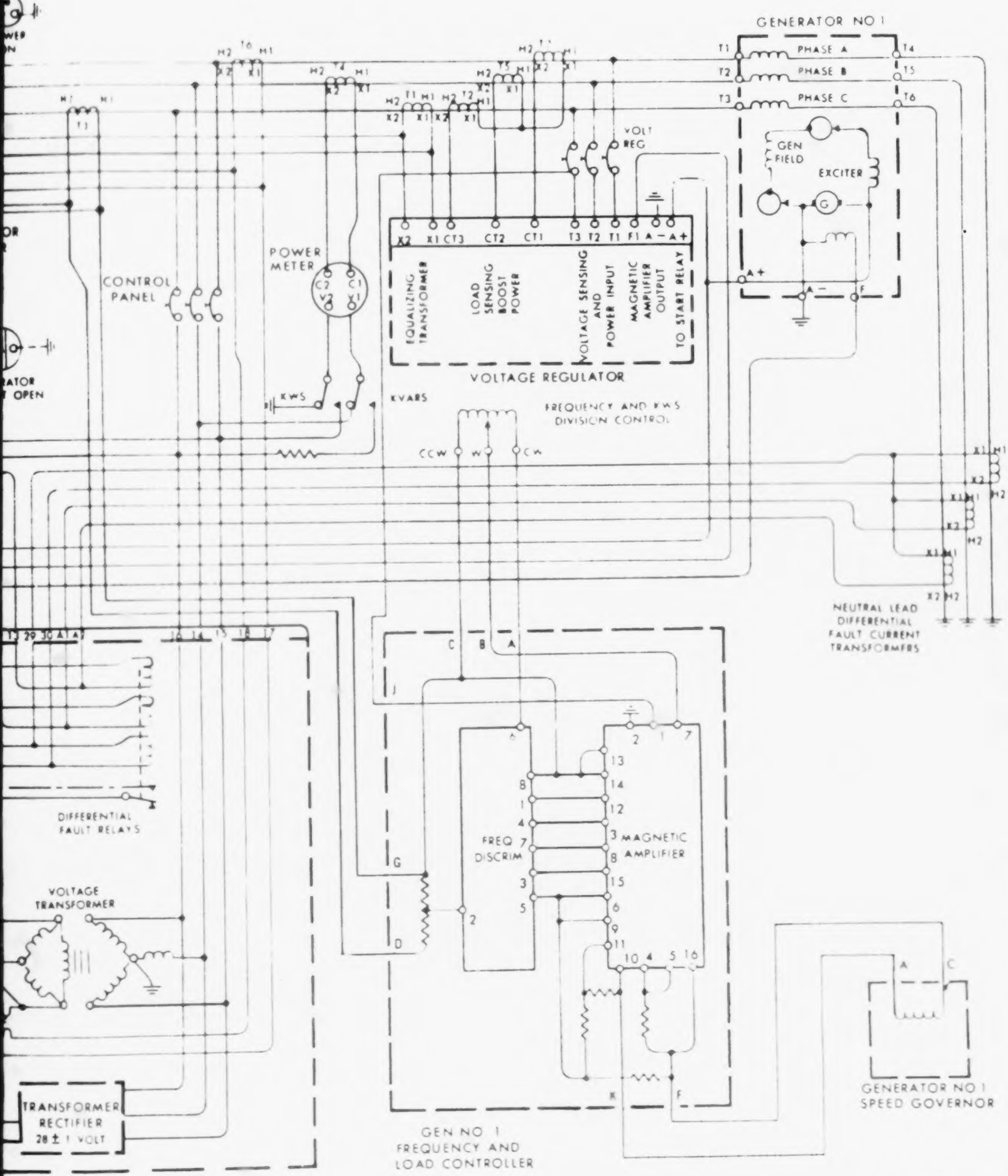
246 – 4. A squirrel-cage rotor.

246 – 5. By reversing any two power leads.

246 – 6. Two phases.

246 – 7. The speed of the rotating magnetic field; the speed of the rotor and magnetic field are locked together and remain the same.


BUS TIE BREAKER NO 3
BUS TIE BREAKER NO 2
EXTERNAL POWER BREAKER
T1
T2
T3
L1
L2
L3
GENERATOR NO 1 LOAD BUS
BUS DIFFERENTIAL FAULT CURRENT TRANSFORMERS
H2
H1
X2
X1
DISTRIBUTION
POWER ON
VOLTMETER
VOLTMETER FREQMETER
SYNC LT PHASE A
VOLTMETER SYNC LIGHT PHASE A
NEG SEQ RELAY
28V DC
BUS TIE BREAKER
SWITCHED DC BUS CIRCUIT BREAKER PANEL
AUX NEG SEQ CONT RELAY NO 1
EXT PWR
CLOSE
OFF
EXT PWR
TRIP
BUS TIE BREAKER SWITCH
VOLTMETER SYNC LIGHT FREQ METER
GENERATOR FAILURE
BUS TIE BREAKER
CLOSE
TRIP
DIM CONTROL
INDICATOR LIGHTS
28V DC SW DC BUS
BUS TIE CIRCUIT OPEN
GENERATOR BREAKER
CLOSE
TRIP
GENERATOR CIRCUIT OPEN
OPEN
EXT PWR BREAKER
PARALLELING SELECTOR
V
F
SYNC LIGHT PHASE C
GEN 1
GEN 2
GEN 3
BUS TIE
EXT PWR
AUTO PAR CONT RELAY
EXT PWR TRIP
CLOSE
OFF
TRIP
GENERATOR BREAKER SWITCH
AUTO PARALLEL UNIT
SENSING CIRCUIT
A
C
D
E
SWITCHED DC BUS CIRCUIT BREAKER PANEL
28V DC
AUTO PAR UNIT
28V DC
GEN PANEL & BREAKER
BATTERY CIRCUIT BREAKER PANEL
FIRE
NORM
ENGINE FIRE SWITCH
GENERATOR CONTROL SWITCH
TRIP
OFF
CLOSE
RESET BUTTON
4
25
26
27
19
20
22
2
21
2
5
8
28
24
11
10
12
13
29
30
A1
UNDERSPEED RELAY
GENERATOR CONTROL RELAY
TRIP
CLOSE
FIELD FLASHING RESISTOR
UNDERSPEED SWITCH
A
C
LOCKOUT RELAY
VOLTAGE INDICATOR RELAY
GENERATOR CONTROL PANEL
THERMAL TIME DELAY SWITCH NO 2
THERMAL TIME DELAY SWITCH NO 1
EXCITER VOLTAGE RELAY
OVER EXCITATION RELAY
OVER VOLTAGE RELAY
UNDER EXCITATION RELAY
DIFFE
FAULT
VOLTAG
TRANSFO
MUTUAL REACTOR
TRANSFOR
RECTIFIE
28 ± 1 VO
CI 82-4550
0-10c


GENERATOR NO 1
PHASE A
PHASE B
PHASE C
T1
T2
T3
T4
T5
T6
GEN FIELD
EXCITER
VOLT REG
X2
X1
CT3
CT2
CT1
F1
A −
A +
EQUALIZING TRANSFORMER
LOAD SENSING BOOST POWER
VOLTAGE SENSING AND POWER INPUT
MAGNETIC AMPLIFIER OUTPUT
TO START RELAY
VOLTAGE REGULATOR
POWER METER
C2
C1
V2
V1
CONTROL PANEL
KWS
KVARS
FREQUENCY AND KWS DIVISION CONTROL
CCW
W
CW
H2
H1
NEUTRAL LEAD DIFFERENTIAL FAULT CURRENT TRANSFORMERS
DIFFERENTIAL FAULT RELAYS
VOLTAGE TRANSFORMER
TRANSFORMER RECTIFIER 28 ± 1 VOLT
C
B
A
J
G
D
K
F
FREQ DISCRIM
MAGNETIC AMPLIFIER
GEN NO 1 FREQUENCY AND LOAD CONTROLLER
GENERATOR NO 1 SPEED GOVERNOR

Foldout 1. AC multigenerator system wiring diagram.

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AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST

(AFSC 42350)

Volume 3

Aircraft Control and Warning Systems

Proficimus More Irretenti

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THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS IS the final volume of this course. It is a most important volume because it deals with a variety of the electrical systems you are required to maintain. In this volume you will be able to relate information previously learned directly to a specific system. The systems used here are typical systems and are not generally identified toward a specific aircraft.

Chapter 1 discusses landing gear systems. Although most landing gears are hydraulically operated, they have been included for good reason. First, most landing gears are electrically controlled, and this is where you, the aircraft electrician, come into the picture. Second, you are required to adjust and calibrate the various switches and actuators in the system; this is so the gears will operate at the precise moment, and in the correct sequence. The intent of this chapter is to provide overview and some familiarity with typical landing gear system tasks.

A great deal of your time will be spent on maintaining the electrical portions of flight control and warning systems. Chapter 2 encompasses operation, inspection, and troubleshooting aircraft warning systems and secondary flight controls. It also includes installation, repair, overhaul, and modification of the stabilizer and aileron trim controls as well as the leading- and trailing-edge wing flaps.

Chapter 3 presents operation and maintenance information on the power plant system, fuel control system, and associated warning systems. The basic operation of a working aircraft's engine (power plant) is taught in such a manner that your efforts on maintaining the various starting and ignition systems may be meaningfully accomplished. In respect to fuel systems, the numerous electrical components involved require a very thorough knowledge of system operation so that you can maintain, troubleshoot, and repair the fuel system control circuits and the control system components. Two sections on warning systems conclude this chapter. These warning systems alert the crew to fires and overheating conditions, and also to the operational status of the aircraft, its landing and takeoff systems, etc. The importance of thoroughly understanding how they are activated and what is involved in maintaining them in a high state of readiness is obviously of much importance. Tasks involving the warning systems will constitute a major part of your duties.

In the final chapter, you will find a detailed maintenance discussion on aircraft lighting systems, both internal and external. The final portion of Chapter 4 deals with typical maintenance procedures applicable to window anti-icing circuits.

Two oversized illustrations are printed and bound in the back of this volume as foldouts 1 and 2.

Code numbers appearing on figures are for preparing agency identification only.

Please note that in this volume we are using the singular pronoun *he*, *his*, and *him* in its generic sense, not its masculine sense. The word to which it refers is person.

If you have any questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to 3350th Technical Training Wing/TTGOX, Chanute AFB IL 61868. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of June 1977.

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NOTE: In this volume, the subject material is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Landing Gear and Associated Systems

AIRCRAFT LANDING gear systems are fairly complex because of the many requirements that must be met. For example, all landing gear systems must have safety circuits to prevent accidental operation of the gear when the aircraft is on the ground. Landing gear systems must also have a warning system so that the pilot does not attempt to land the aircraft with the landing gear retracted. Another requirement is that the landing gear system be equipped with an indicating system to show the pilot the position of the landing gear, i.e., up and locked, down and locked, or in an unsafe position. In addition, most landing gear systems have antiskid protective devices that reduce the possibility of a blown tire during landing. Also associated with the landing gear system is the steering mechanism, which provides maneuverability when the aircraft is on the ground.

What does this mean to you as an aircraft electrician? Although most landing gear systems are hydraulically operated, many are electrically controlled. This means that you are responsible for maintaining the electrical components of landing gear and associated systems. You must be able to troubleshoot these systems, bench-test the components, and make adjustments on limit switches and other components as necessary. You are also required to make operational checks of these systems.

1-1. Landing Gear Operation and Maintenance

The landing gear system selected for this discussion is the one used on the C-130. It contains a nose landing gear, two main landing gears, limit switches, an unlocked solenoid, and a control unit. The control panel contains three landing gear position indicators, a control handle, a warning light press-to-test switch, and a horn silence switch, which will also be discussed. The electrical portion of the landing gear system is similar in operation for all aircraft having retractable landing gears; therefore, to list more than one system in this CDC would be too repetitious. The main difference between the systems is the location of components such as the indicators, landing gear handles, warning horns, horn silence buttons, and light test buttons. The limit switches are all located on the landing gear struts and in the wheel wells.

400. Analyze facts relevant to the operation of the main and nose landing gear retraction and extension circuits and draw conclusions about the function of these circuits.

Operation. In order to operate the landing gear, only one manual operation must be performed; that is, move the gear control handle to either the gear UP position after take off, or to the gear DN position prior to landing. In a properly operating landing gear system, everything else is automatic. Our first discussion concerns the components that make up the landing gear system. After you have studied the components, we will put them together to see how the system operates.

Control panel. The control unit, see fig. 1-1, is located on the left hand side of the copilots instrument panel. It contains three gear position indicators, a gear control handle, a horn silence button, a handle light test switch, and a warning light located in the gear handle. A locking solenoid located under the control panel is not shown. As you can see, most of the components of the control circuit are located on this panel.

Limit switches. Several limit switches are used in the landing gear circuits. The nosegear has one uplimit switch and one downlimit switch. Some C-130 aircraft have two downlimit switches. You must

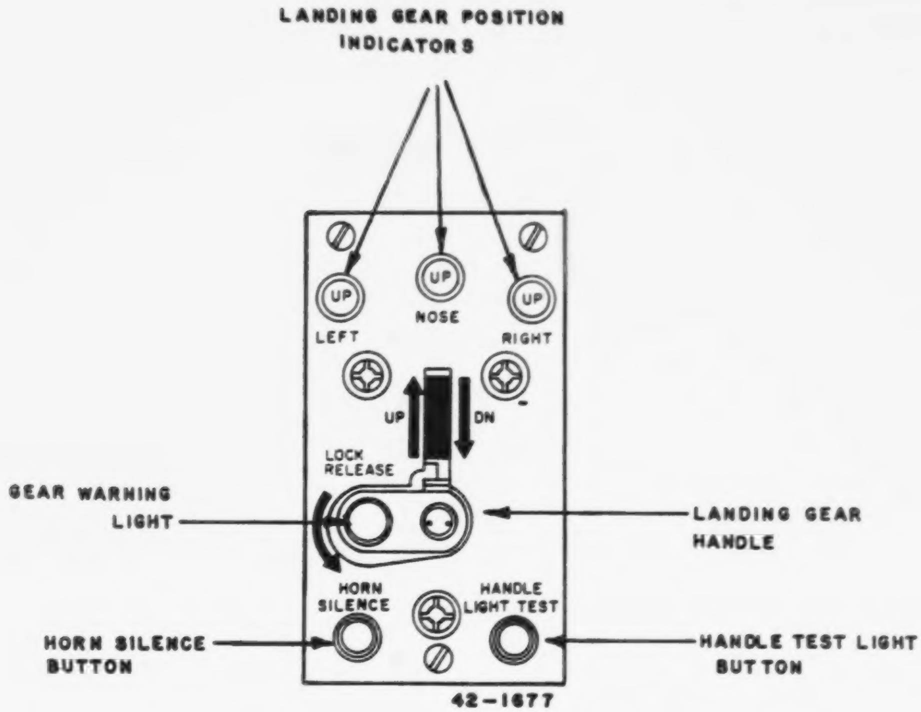


Figure 1-1. Landing gear control unit.

check the technical order for the aircraft you are working on to determine how the system is hooked up. The limit switches are the adjustable plunger type. The main gear also has uplimit and downlimit switches in addition to touchdown switches. These switches are straight plunger type.

This limit switch is a mechanically operated switch that is actuated by movement of either the landing gears, the landing gear handle, or the throttles. Limit switches can be either normally open or normally closed. In this way, when they are actuated, they can open or close an electrical circuit, depending upon the requirements. These circuits can operate hydraulic valves to control fluid flow, which will raise or lower landing gears. They are also used to operate warning lights, horns, and to produce signals which identify the actual position the landing gear is in at any given time.

When the gear handle is placed in the down position, current from the 28-volt essential DC bus flows through the control handle to the down solenoid on the landing gear selector valve, opening it (reference foldout 1). Pressure then flows to the right and left main landing gear hydraulic motors to lower the main gears. Pressure also flows to the unlock side of the nose landing gear uplock cylinder and the nose landing gear actuating cylinder. The uplock cylinder releases the gear, and then the actuating cylinder extends the nosegear.

When the airplane is in the air, current flows from the 28-volt isolated DC bus (reference foldout 1), through the right and left landing gear touchdown switches to the touchdown relay, energizing its coil. Current also flows from the essential DC bus to the control handle unlock solenoid when the control handle is in the DN position. A ground is applied to the other side of this solenoid through contacts of the touchdown relay, energizing the solenoid. This allows either up or down movement of the control handle. When the airplane touches down, the touchdown switches are actuated, opening the circuit to the coil of the touchdown relay. This deenergizes the control handle unlock solenoid, locking the control handle in the down position.

When the airplane is in the air, placing the landing control handle in the UP position applies power from the 28-volt essential DC bus through the control handle to the up solenoid on the landing gear selector valve. Pressure then flows to the right and left main landing gear actuating motors, which raise the main gear. Pressure also flows to the nose landing gear down-lock cylinder, releasing the lock as well as the nose landing gear actuating cylinder, which will raise the nosegear. When all three gears have fully retracted, the up limit switches will actuate and open the circuit. This closes the landing gear selector valve and shuts off the system pressure to the actuating motors.

Exercises (400):

1. With the aircraft on jacks and applicable power applied to the landing gear mechanism, what would you do to make the landing gear go to UP or DN position?

2. When the gear selector valve is opened, what four components receive hydraulic pressure?

3. What must occur before the actuating cylinder can extend the nosegear?

4. What conditions must be satisfied before electrical power can be applied to the up solenoid on the landing gear selector valve?

401. Analyze facts and specify conditions relevant to the operation of the landing gear warning system.

Landing Gear Warning Circuit. The landing gear warning system consists of a warning horn, a horn silence switch, and a horn silence relay. It also controls the warning light in the gear control handle. As you will recall from our previous discussion, the red warning light comes on when the gears are not fully extended or retracted. The brightness of this light is controlled by a two position DIM, BRIGHT switch located on the pilot's instrument panel. Warning lights in aircraft have been standardized to make them easily recognized by the crews as to which one is the most critical. Red warning lights identify hazardous or critical conditions, amber lights signify caution or a condition that could become critical. Green lights, as you probably guessed, show conditions are satisfactory.

The warning horn is located overhead; just slightly behind the pilot's seat. It warns the crew when the landing gear is *not* down and locked and *any* throttle is retarded below minimum cruise power. It will also actuate when the gear is not down and locked and when the wing flaps are less than 75 percent extended. The horn may be silenced by energizing the horn silence relay through the horn silence switch if the horn was blowing due to a closed circuit through the throttles.

When the landing gear control handle is in the UP position, current from the 28-volt essential DC bus flows through the dimmer circuit to the warning light. When the landing gear is not up and locked, a ground is supplied by any one of the landing gear uplimit switches, by way of contacts in the control handle, to the other side of the warning light. This causes the red warning light to go on, indicating to the pilot that the gear is not locked in either the UP or DN position. When the landing gear is fully retracted, the uplimit switches are actuated, opening the circuit. With the landing gear control handle in the DOWN position, power from the essential DC bus flows through the dimmer circuit to the warning light (see foldout 1). When the landing gear is not down and locked, a ground is supplied by any one of the landing gear downlimit switches, by way of contacts in the control handle, to the other side of the warning light. This causes the warning light to go on. When the landing gear is fully extended and locked, the downlimit switches are actuated, opening the circuit, extinguishing the light. If any throttle is retarded below minimum cruise power when the landing gear is not down and locked, a ground is supplied by any one of the landing gear downlimit switches, through contacts on the retarded throttle to the other side of the warning light. This causes the warning light to go on. The circuit is opened when the retarded throttle is advanced above minimum cruise power or the landing gear is fully extended, actuating the downlimit switches.

The wing flaps also play an important part in the circuit. Let's see how this works. Current from the 28-volt essential DC bus (reference foldout 1) flows directly to the warning horn. If the wing flaps are at least 75 percent extended and the landing gear is not down and locked, a ground will be supplied by any one of the landing gear downlimit switches to the other side of the warning horn. This causes the warning horn to sound. The circuit is opened when the wing flap control lever is positioned below 75 percent extension. It will also open when the landing gear is fully extended, actuating the downlimit switches. If the landing gear is not down and locked with any throttle retarded below the minimum cruise power and the horn silence relay open, a ground is supplied by any one of the landing gear downlimit switches to the other side of the warning horn. This causes the warning horn to sound. The circuit can be opened by advancing the retarded throttle above minimum cruise power or by pressing the horn silence switch. The circuit is also opened when the landing gear extends fully, actuating the downlimit switches.

Current from the 28-volt essential DC bus flows directly to the warning horn and horn silence relay. When the warning horn is sounding due to a closed circuit through any throttle switch, it can be silenced by momentarily pressing the horn silence switch. This applies a ground to the other side of the horn silence relay. This causes momentary closing of the relay and setting up a lock-in circuit to maintain a closed circuit for a silencer relay associated with the particular throttle. This lock-in circuit is opened either by advancing the appropriate throttle or fully extending the landing gear. Retarding another throttle below minimum cruise speed will again sound the warning horn. The horn may be silenced in the same manner as previously described.

Exercises (401):

1. What two conditions exist when the landing gear warning horn sounds off?

2. a. When the uplimit switches are actuated, this opens what circuit? Which does what?

   b. Under what condition does the downlimit switch become actuated?

3. a. Momentarily pressing the horn silence switch applies a ground to what?

   b. What keeps the horn silent after the momentary pressing noted above? Explain.

   c. If another throttle goes below cruise speed, will the warning horn again sound off? Explain.

402. Identify principles or procedures used when inspecting and troubleshooting landing gear systems.

Inspection. When inspecting the landing gear system, you must look for several things. Check the wiring in the wheel well for signs of deterioration, binding, and security. Limit switches should be secure and free from dirt. Be sure that wire bundles are properly attached to the struts and aircraft so that movement of the gear will not pull or cut the bundles.

Check the circuit-breaker panel for security of mounting of circuit breakers and wires. Make sure the light in the gear handle is operating by pressing the handle light test button. Also check the indicators to see that they read DN when power is on and intermittent or "barber pole" when power is turned off. If the indicators stick, they must be replaced. Make sure you use the inspection workcards so that nothing will be overlooked.

Troubleshooting. How well you do on your job as an aircraft electrical systems specialist depends on the skill that you attain. That skill is the ability to troubleshoot, which consists of more than just going out to the aircraft and hunting for the trouble. A systematic approach should be used when troubleshooting. The first thing you should do is analyze the problem to determine what is wrong. You do this with the aid of wiring diagrams, schematics, and technical orders. If you try to repair an aircraft without full knowledge of the system, you will waste time and possibly cause more and serious damage. You must also remember to check the aircraft history, to make sure the problem is not a repeat discrepancy.

Let's look at typical problems that could be encountered while troubleshooting the landing gear system. Suppose you were handed a work order that says, "The left main gear will not retract." What action is then taken?

To begin with, other shops will be working with you to locate the trouble, mainly the hydraulic shop. Of course the aircraft will have to be placed on jacks to make possible preliminary checks, and also an operational check after the problem has been remedied.

After electrical and hydraulic power has been applied, the gear handle (which controls the landing gear control switch) is raised. All gears except the left main gear rise and lock. Safety pins are installed in the defective gear linkage to prevent it from operating while you make further checks into the problem. Since the problem is only in the left gear, our first check would be to see if there is power to the UP side of the landing gear (LG) selector valve. (Reference foldout 1 and note that the left gear is located in the LH main wheel well.) You would remove the connector plug (not shown on diagram) from the LG selector valve (shown on the right upper corner of foldout 1). Check for power to the UP side, and if we have 28 volts DC here, the trouble must be between that point and ground. If you did not read 28 volts DC here, the trouble would have been between that point and the essential 28-volt DC bus. For this problem we will say that we had the required voltage up to the LG selector valve.

The remainder of our troubleshooting will now be with an ohmmeter, so remove power from the aircraft. Now check for continuity from the connector plug's other terminal to ground. Here we find a complete circuit by our reading of zero ohms. We have now isolated the problem to the selector valve, so our next check would be across the UP coil in the selector valve. Here we read infinity — a complete circuit does not exist. The selector valve will have to be removed and replaced. An operational check would then be performed to ensure that the replaced item operates satisfactorily.

Now consider the same problem as just described, only this time when we check the ground, we have an open circuit. Since the connector plug is off of the selector valve, check the UP coil with the ohmmeter. Assume you find that the reading there is good. Reinstall the connector plug and apply electrical power. Take a voltage reading at the ground terminal of the MLG UP-POSITION IND SW. Let's say the reading is 28 volts DC. You now know that power is getting from the essential bus, through the selector valve, and all the way to ground. But, should you read 28 volts DC on the ground terminal? No, you should read 0 volts. Anytime, you read voltage on the ground side of anything and the system does not operate, it means that you have an open to ground. This could be caused by a broken ground connection or corrosion between the connections to ground. Once the ground is repaired, an operational check must be performed.

Looking at a little different problem, say the gears went up but the left main gear indicator showed an unsafe condition. (Assume that the aircraft is still on jacks and electrical and hydraulic power is being applied.) Cycle the gear handle to the UP position. In this problem you see that all gears go up and lock, however, the indicator does not indicate UP. The best place to check this problem is at the indicator, since all the gear is up and locked and you cannot work in the wheel wells. Referring to foldout 1, let's simulate the troubleshooting. First, remove the connector plug (not shown) on the LEFT POS IND and check for power. Reading 28 volts DC here, we would check the ground side of the connector plug with an ohmmeter. Reading zero ohms here indicates that the ground circuit is good. You then check the indicator with an ohmmeter and you will find that the UP coil (not illustrated) is open. The indicator would have to be replaced and an operational check made of the system.

Other more complicated problems could exist between the points we discussed, in which case you would refer to the appropriate wiring diagram for that system. Should you need to locate a trouble such as a broken wire in the system, the wiring diagram will show you the terminal strips and connector plugs, and identify their general location. The same overall procedures are followed for other troubles, and a defect will always be between the last good reading and a defective reading.

In the repair stage, you may have determined from your troubleshooting that either a wire was defective or a component was malfunctioning. In either case, you must repair the trouble. Naturally, if the trouble is a broken wire, it should be repaired in accordance with current tech data. If the problem is a defective component, such as an open limit switch, the limit switch should be replaced. Again, use the technical order for tolerances and torque values. After repair has been made, you must perform an operational checkout before signing it off.

The operational check is a very important step. This must be done after any repair has been completed. You will want to know if the repair you did completely corrected the problem. Sometimes you will find two or more problems in the same circuit, so when you perform your operational check, the other problem may then show up. The only way you can operationally check the landing gear system is to have it up on jacks. Hydraulic power as well as electrical power must be externally applied when performing.

Exercises (402):

1. a. What must you look for when inspecting the wiring in wheel wells?

   b. When inspecting the circuit breaker panel, what should you inspect for?

2. To check out a faulty landing gear system, what steps should be initiated prior to troubleshooting?

3. All essential 28 VDC bus systems work OK; however, sometimes we have intermittent power when raising or lowering the landing gear. List four or more places to check.

403. Cite authorized procedures or practices relative to maintaining the landing gear system.

Maintaining the Landing Gear System. In order to maintain the landing gear system properly, there are also other things that must be learned. You must know how to properly install components, how to bench-check components, repair components, and modify and overhaul components. Let's briefly look at each of these.

Installation of components. Items such as the landing gear control switch, LG high torque switch, LG selector valve, touchdown relays, silencer relays, auxiliary touchdown relays, and various circuit breakers, panels and racks all are involved in the maintenance of the landing gear retraction and extension system. The maintenance or repair of these items is normally limited to remove and replace. They are generally identified as XB2 items, i.e., a base expendable item; however, items designed for adjustment, such as limit switches, can and should be adjusted as necessary. Naturally, all components must be installed in accordance with tech data. Limit switches, such as the ones previously discussed, must be installed properly or the pilot will get false indications on his gear. These limit switches have to be adjusted after they are installed. Certain tolerances are listed in technical orders. Cycling the gear on jacks is necessary to properly adjust them after installation.

Bench check and repair of components. The components discussed in this section are mainly the remove and replace type items. The limit switches can be checked with an ohmmeter to determine if they are operating properly. Normally, there is no repair to them.

Modification and overhaul of components. If a component continues to fail for the same reason, a deficiency in the part is indicated. For safety reasons, an entire system may need to be changed. Whatever the reason may be, the change is called a modification. A modification must be approved by AFSC (Air Force Systems Command), and this approval is then adopted in the form of a TCTO (time compliance technical order). The TCTO tells you when, where, and how the modification is to be done. Modifications are either done at a major repair and overhaul facility for the aircraft or by you on the flight line. All parts to complete the modification are included in a kit that comes with the TCTO. Modifications are as far as you can go. Overhaul of electrical components of landing gear systems is practically nonexistent. "Remove and replace" is normally all you will do in this system when a defective part is found. Remember, after repair/replacement IAW an applicable TO, an operational check IAW an applicable TO is also required.

Exercises (403):

1. Assuming that you have found the LG selector valve as having an open UP coil:
   a. What should be involved with its removal?

   b. If it's an XB2 item, where should it be repaired, at base or depot level? Explain.

   c. What should be involved with its replacement?

   d. After proper replacement, the next major step is to do what?

2. If warning horn silencer switches had to be depressed for longer periods of time to actuate silencer relays:
   a. Who would have to approve a corrective modification?

   b. When approved, what generally would be used to implement it?

   c. Where would the modification components come from?

   d. After proper installation, what should be done next?

1-2. Antiskid System

Many systems have been incorporated into aircraft since the early days of flying. Each new system generally makes flying easier for the crew. In order for these systems to function properly, trained specialists must know how to maintain them. One of the systems, which we are about to discuss, is the antiskid system. This system, when engaged and working properly, enables the pilot to keep the aircraft straight on the runway after touchdown. The antiskid system operates in conjunction with the braking system to slow and stop the aircraft. This is done by engaging the antiskid system prior to landing and pressing on the brake pedals. The antiskid system prevents wheels from locking up and skidding. When the wheels turn rather slowly, very little hydraulic pressure is allowed to be applied to the brakes. Conversely when the wheels turn fast, more hydraulic pressure is applied to the brakes, and the wheels slow down. The system also has an electrical checkout and fail-safe system that automatically checks the system when power is first applied.

404. Point out how the various relays operate in the antiskid circuit.

Operation. The antiskid system is used to prevent skidding and locking of aircraft wheels. The system consists of a skid detector mounted on each main wheel, an antiskid control valve, antiskid control boxes, and an arming relay control box. Each skid detector has a sensing element that detects the rate of change of wheel speed and another that detects wheel rotation speed. The change-of-speed sensing element is the first element to sense a skid condition and it prevents it from progressing. Wheel locking is averted by the rotation-speed sensing element. A "fail-safe" action assures that the brakes may be operated under any circumstance. The circuit also contains an antiskid inoperative light that glows red when the antiskid system is not operating.

Relays in the antiskid circuit are identified by the letter "L" and by letters "V" through "Z." These letters correspond to those shown on the schematic diagram, figure 1-2, and provide an easy method of matching the text with diagrams.

The valves used in the antiskid system are electrically controlled; these valves regulate the fluid used

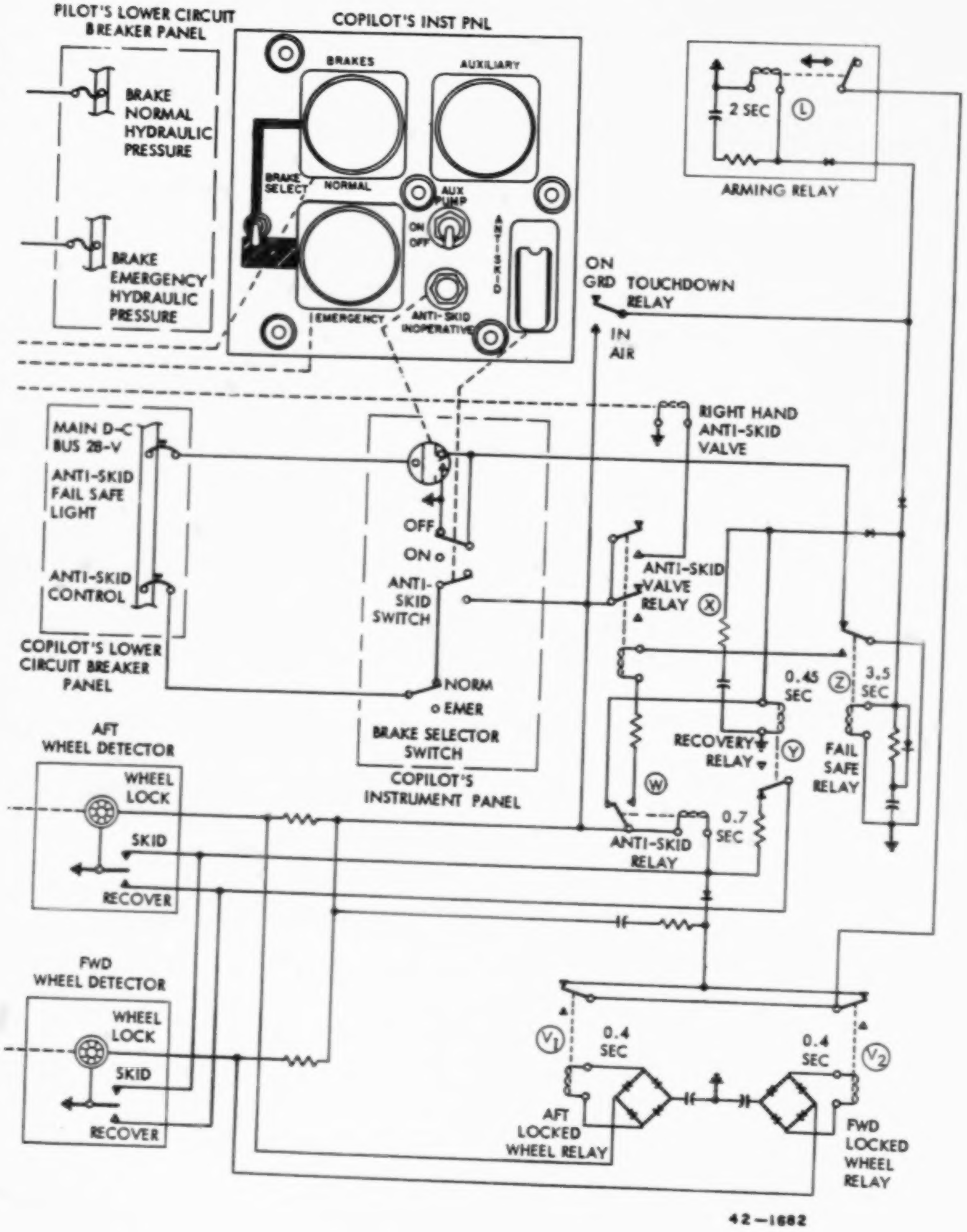

PILOT'S LOWER CIRCUIT BREAKER PANEL
BRAKE NORMAL HYDRAULIC PRESSURE
BRAKE EMERGENCY HYDRAULIC PRESSURE
COPILOT'S INST PNL
BRAKES
AUXILIARY
BRAKE SELECT
NORMAL
AUX PUMP
ON
OFF
ANTI-SKID
EMERGENCY
ANTI-SKID INOPERATIVE
2 SEC
Ⓛ
ARMING RELAY
ON GRD
TOUCHDOWN RELAY
IN AIR
RIGHT HAND ANTI-SKID VALVE
MAIN D-C BUS 28-V
ANTI-SKID FAIL SAFE LIGHT
ANTI-SKID CONTROL
COPILOT'S LOWER CIRCUIT BREAKER PANEL
OFF
ON
ANTI-SKID SWITCH
NORM
EMER
BRAKE SELECTOR SWITCH
COPILOT'S INSTRUMENT PANEL
ANTI-SKID VALVE RELAY Ⓧ
0.45 SEC
Ⓩ
3.5 SEC
RECOVERY RELAY
Ⓨ
FAIL SAFE RELAY
Ⓦ
0.7 SEC
ANTI-SKID RELAY
AFT WHEEL DETECTOR
WHEEL LOCK
SKID
RECOVER
FWD WHEEL DETECTOR
WHEEL LOCK
SKID
RECOVER
V1
0.4 SEC
0.4 SEC
V2
AFT LOCKED WHEEL RELAY
FWD LOCKED WHEEL RELAY
42—1682

Figure 1-2. Antiskid schematic.

in the various lines. It can direct the fluid to flow to an actuator, or return the fluid to a reservoir. A typical example would be in the antiskid system where brake pressure is applied to the brakes. When the antiskid system detects a skid, the valve sends fluid to the reservoir instead of the brakes. This allows the wheels to turn without brake pressure applied until the rotation of the wheels reach a speed equal to the aircraft's speed, then brakes are applied again to slow the aircraft down. The antiskid control valves are three-way, solenoid operation valves. When they are energized, they route hydraulic pressure around the brake actuator, bypassing the brakes. Normally these valves are deenergized, and the pressure goes directly to the brakes for normal braking operation.

When the antiskid switch (see fig. 1-2) is placed in the ON position, the brake selector switch in the NORMAL position, and the aircraft is in the air, 28 volts DC from the main bus energizes relays "L," "X," and "Z." Relays "Y," "V_1," and "V_2" are deenergized. Let's see how this is done.

First of all, the aircraft is in flight, so the touchdown relay will be in the IN AIR position. Therefore, start with the "Z" relay. Current will flow from ground through the coil, through the closed contacts (IN AIR) of the touchdown relay, through the antiskid switch and the brake selector switch to the main 28 volt DC bus.

The "L" relay is energized by a circuit which is completed from ground, through the coil, through the closed contacts of the touchdown relay, the antiskid switch, and the brake selector switch to the main 28 volt DC bus, energizing the "L" relay. When this relay energizes, it supplies the ground for the "W" relay.

The "W" relay is energized by a circuit completed from ground, through the contacts of the "L" relay, through the contacts of the "V_1" and "V_2" relays, through the "W" relay coil, then through the antiskid switch and the brake selector switch to the main 28-volt DC bus. When the "W" relay energized, it allowed current to be directed to the "X" relay coil. Starting with the ground on the "Z" relay, current goes through the "Z" relay contacts, through the "X" relay coil and resistor, through the "W" relay contacts, through the antiskid switch and brake selector switch to the main 28-volt DC bus, energizing the "X" relay. This circuit is provided as a safety measure so that brake pressure is not applied after the aircraft has left the ground.

Upon touchdown, a signal is received from the skid detector, which causes the "V" relays to become energized. When this happens, the ground circuit to the "W" relay is opened and in approximately 0.7 second, the "W" and "X" relays open. Opening the "X" relay deenergizes the antiskid control valve and allows metered brake pressure to reach the brakes after the landing gear wheels have accelerated upon touchdown.

When a skid signal reaches the control box, the "W" relay receives a ground and is energized. This energizes the "X" relay that furnishes power to the antiskid control valve which releases the brakes.

The "Y" relay is energized when the "W" relay is deenergized and will open in approximately 0.45 second. The built in time delay keeps the "Y" relay energized during a skid shorter than 0.45 second. If the skid is longer than 0.45 second, the "Y" relay will open, which will place a ground on the "W" relay. The "W" relay remains energized through the entire recovery signal. When the recovery signal stops, the opening time of the "W" relay is reduced to a very short interval. This is due to the reduced magnetic field in the holding coils. As soon as the "W" relay opens, metered brake pressure is again available to the brakes and the skid and recovery braking cyle can be repeated.

The "Z" relay provides a fail-safe feature for the circuit and is adjusted to open after approximately 3.5 seconds. During brake cycling by the "W" relay, the "Z" relay is alternately recharged by action of the "W" relay cycling. The "Z" relay will be continuously charged when the "W" relay is not energized. The "Z" relay is also energized through the touchdown relay. System faults, which might cause a continuous skid signal (brakes released) of more than 3.5 seconds, will cause the "Z" relay to open and the braking system will revert to normal manual operation. If the fault somehow clears itself, the antiskid system will automatically start working again. The antiskid inoperative light operates off of the "Z" relay and will be on anytime the "Z" relay is not energized or when the antiskid switch is in the OFF position.

The "L" relay operates through the use of the touchdown relay to apply power to the skid control circuit by providing an alternate ground. This is done through the "V" relays which energize the "W" relays and release the brakes before touchdown.

As soon as the weight of the aircraft settles on the landing gear, the touchdown relay opens, which opens the circuit to the "L" relay. The "L" relay has an opening time-delay of approximately 2 seconds so that the wheels will not lock during the initial part of the landing when weight on the wheels may be very light and the brake pressure high.

The "V" relays are powered by the alternate charging and discharging of a capacitor in the coil circuit. The charging and discharging is caused by the alternate application of ground and open circuits by the rotating skid detectors. The "V" relays are normally energized when the rotor turns above 25 RPM. They also provide part of the ground circuit to the "W" relay to release the brakes before touchdown. They also release the brakes in the event of a complete loss of rotational speed of any wheel before the "L" relay opens. The "X" relay connects the power to the antiskid control valve and has no time delay.

Exercises (404):

1. What type of antiskid control valves are used in the system?

2. With the aircraft in flight, the antiskid switch ON, and the brake selector switch in the NORMAL position:
   a. What relays are energized?

   b. What relays are deenergized?

3. Where do the relays get their power from?

4. What other relay opens when the "W" relay opens, and what is the time delay?

5. What is the "Z" relay used for, and what is its time delay?

6. What really operates the antiskid inoperative light?

405. Identify inspection and troubleshooting procedures.

Inspection. When inspecting the antiskid system, you must look for signs of deteriorating wires, components that are not secure, binding and security of wires. Make sure all connector plugs are secure on the components and that the components themselves are securely mounted. In places where safety-wire is to be used, make sure it is properly installed.

On all phased inspections, you will have inspection workcards to follow. These contain each item that is required to be inspected during that particular inspection. As long as you follow the directions on them, you should not have any problems with the inspection and the antiskid system should operate much more trouble free.

Troubleshooting. Regardless of knowledge of the antiskid system, troubleshooting must be done with the aid of current technical data. It is true that you do some jobs so many times that you know all the procedures word for word. However, always check the applicable TO! Often changes are made in the system that changes procedures. In these cases, not using current technical data could very well endanger lives and equipment. Do not rely on your memory or training material such as this CDC; instead, always go by up-to-date troubleshooting technical data.

Troubleshooting charts are located in most technical orders to assist you in locating troubles. For instance, if the pilot writes, "the antiskid inoperative light is not working when the system is turned off." The troubleshooting chart directs you to check the bulb, and possibly, change it if defective. If this does not fix the problem, the TO may suggest that you check the "Z" relay. In most cases, the "fixes" for the troubles identified in the TO will repair the malfunction. When they don't, you will have to use your knowledge and skill, along with schematics, wiring diagrams, and test equipment to locate and repair the troubles.

To assist you in troubleshooting the antiskid system, a test set is used. To use this test set, we need external hydraulic pressure to pressurize the utility system and external electrical power. The skid detectors are rotated and lights on the tester are checked against troubleshooting procedures in the TO. The test set also has switches that simulate skid and recovery situations. Brake pressure is also monitored.

Anytime a component in the antiskid system has been replaced, or it is suspected that the system is not working properly, an operational check must be performed. This is done to ensure that the malfunction you repaired was the only thing that made the system defective. We must also make sure that the system is operational before it is signed off as ready for flight.

Exercises (405):

1. What should you look for when inspecting connector plugs?

2. What is used to aid you on phased inspections?

3. What type material can be used to troubleshoot an aircraft electrical system?

4. What is the final step of troubleshooting?

406. Cite authorized procedures or practices relative to maintaining the antiskid system.

Maintaining the Antiskid System. In order to maintain the antiskid system properly, in addition to knowing how the system operates, you must be able to do other things. You must install, repair, overhaul and modify components. We will take a brief look at each of these items.

Installing components. Anytime a component is installed on an aircraft, care must be taken to make sure that the component is suitable for that particular installation. If the prime item cannot be obtained, an authorized substitute may be used. Installation of this substitute item is not permissable if it does not have the same specifications as the prime item. All components are installed using the procedures and torque values listed in the applicable technical orders.

Repair of components. Once an electrical component in the antiskid system is found to be defective, a new replacement component is put on. Repairs on these components are not feasible as they are either sealed units or are too sensitive to withstand repair. Remove and replace is generally the authorized repair.

Modification and overhaul of components. If replacement components fail for the same reason, it indicates that there is a deficiency in the part. For safety reasons, sometimes entire systems may need to be changed periodically. For whatever reason a modification is called for, it must be approved, and this approval must come in the form of a TCTO (time compliance technical order.) This TCTO will tell you when, where, and how the modification is to be done. Modifications are either done at a major repair and overhaul facility for the aircraft or by you on the flight line. All parts needed to complete the modification are included with the TCTO. Modifications are as far as you can go. Overhaul of the electrical components of the antiskid system is practically nonexistent. "Remove and replace" is normally all you will do when a defective part is found.

Bench check of components. Since components in the antiskid system are either expendable or require expensive, complex, repair and test equipment, bench testing of components at field level maintenance is virtually nonexistent at most bases. An authorized testing unit is generally used at the site to determine if the unit or component in question is properly functioning. Locally manufactured testers are sometimes devised which can be used to pretest replacement items, and thus insure that time is not wasted on installing a new, but faulty, item. This type of locally manufactured tester is also frequently used to double-check the component considered defective, and tests it under conditions isolated from the aircraft's associated circuits; which, in some cases, have a way of making a good component check out faulty.

Exercises (406):

1. When an item is replaced on an aircraft and the prime item cannot be obtained, what can be used and what should you check for?

2. When failure of a component is found in the antiskid system, what repair may you perform?

3. To insure that a unit is actually faulty, and the problem is not caused by an associated circuit, what item is often devised?

1-3. Nose Gear Steering System

This section discusses the nosewheel steering system. The system selected for the discussion pertains to the F-4 aircraft. We will see how it operates, identify procedures to follow while inspecting and troubleshooting it, and give some coverage on the installation, repair, overhaul and modification of its components. We will begin our discussion with the components in the system, then proceed to the systems operation. This will be followed with coverage on general maintenance, which includes inspecting, troubleshooting, installing, repairing, modifying, and overhauling nose gear components.

407. List the components that make up the nose gear steering system and tell what they are used for.

Components. We will discuss 14 components in the nose gear steering system and tell you the function of each. This is important if you are to understand the operation of the complete system.

Nose gear steering switch. A nose gear steering switch is located on the flight-control stick in both cockpits. Its function is to engage the nose gear steering system when either cockpit switch is depressed and the aircraft is on the ground.

Auxiliary air door relay. The contacts of the deenergized auxiliary air door relay provide a path (through its normally closed contacts) for 115 volts AC to energize the power transformer in the nose gear steering control box. When the landing gear control handle is in the UP position, this relay is energized, and the 115 volts AC is removed from the control box.

Nose gear steering control box. (Reference foldout 2.) The control box is a hermetically sealed, solid state device. When using nose gear steering, the control box utilizes signals produced by both the command potentiometer and the followup potentiometer to control direction and degree of turn. The control box is broken down into four circuits: power supply, differential amplifier, failure detection, and automatic checking.

The power supply consists of a power transformer, two full wave rectifier networks, and three resistor-capacitor filter networks (not illustrated). The 42-volt output from the power supply is applied to the command potentiometer (pin B of connector 59P404), and to the followup potentiometer (pin B of connector 59P402); the +56-volt output is applied to the center tap of the servo valve; the −24 volt outputs are applied to both the automatic checking circuits and the differential amplifier.

Command potentiometer. NOTE: Command potentiometer 59R401 (upper right corner of foldout 2) ties into connector 59P404, pins A, M, and B (upper left corner of foldout 2). The command potentiometer is a silicone oil filled device. It produces a high system gain for steering around the outer limits of the nose gear travel. It also produces a low system gain for fine steering around the neutral point of nose gear travel. A 500-ohm resistor is placed in series with the wiper to protect it from excessive arcing. Beyond the resistance function, there are shorting bars for small to medium wiper position changes. The wiper positions cover 70° left and right of center (neutral), i.e., 140° total. This in turn governs nosewheel steering to the same 140°. The remaining portion of potentiometer rotation presents an open circuit to the wiper. The wiper arm of the command potentiometer is mechanically linked to the rudder pedal torque tube. When the rudder pedals are in any position other than neutral, the error signal produced is fed into the differential amplifier of the control box. This will allow the nose gear to start turning in the desired direction.

Followup potentiometer. (Reference foldout 2.) The followup potentiometer is a variable resistor with a linear resistance characteristic. The potentiometer is a fluid filled, plastic element type, with a resistor in series with the wiper. The wiper arm is geared to the power unit. The output of the followup potentiometer determines the degree to which the nose gear turns.

Nose gear steering servo valve. (Reference foldout 2.) The servo valve is an electro hydraulic type jet control valve. When the control box receives a command signal, current through one coil of the torque motor is changed to unbalance the motor armature. After the armature is balanced, by the nose gear turning to a new heading, it will remain in that position until the control box again changes the amount of current flow through one of its coils.

Nose gear steering selector valve. The selector valve (not illustrated) is a remote controlled, three-way, two piston, single solenoid valve. It directs utility hydraulic system pressure to the nose gear steering system. The selector valve cannot be energized until relay K1 is energized. NOTE: Relay K1 in the SCR failure detection unit (left lower corner of foldout 2) connects ground to pin G of connector 59P404, which ties into the selector valve.

Nose gear up relay. (Not illustrated.) This relay is energized when the aircraft weight is off of the landing gear. (This is done through the right main gear scissors switch). It is also energized when the nose gear is not down and locked. (This is done through the nose gear down limit switch.) When it is energized, the circuit to the selector valve is opened. This prevents actuating the selector valve when the aircraft is in flight.

Bypass valve. The bypass valve is an integral part of the power unit (reference lower right of foldout 2). When the steering mechanism is energized through the nosegear steering switch, hydraulic pressure shifts the bypass valve to open hydraulic pressure and return ports in the power unit. When steering is deenergized, the valve shifts in the opposite direction. This blocks these ports and opens the ports to the two one-way restrictors. The fluid trapped by the bypass valve, plus that held under pressure by the compensator, is metered through the orifices in the one-way restrictors to dampen wheel shimmy.

Compensator. (Reference foldout 2.) The compensator is used to maintain back pressure in the power unit return line. This prevents cavitation of the vane motor and dampens nosewheel shimmy when the steering is not engaged.

One-way restrictors. (Reference foldout 2.) There are two one-way restrictors that are an integral part of the power unit. They aid in dampening wheel shimmy.

One-way restrictor. (Reference foldout 2, Nr 59RA4M60.) A one-way restrictor in the fluid bolt attaches the return line universal fitting to the power unit. This dampens rapid bypass valve spool movement when pressure is applied.

Two-way restrictor. (Not shown, item is to the left of the 59FA4M65 filter, lower left corner of foldout 2, on the selector valve of the nose gear wheelwell.) The two-way restrictor bypasses the selector valve and keeps the power unit full of fluid during shimmy dampening.

Power unit. (Reference foldout 2.) The power unit is mounted on the nose gear strut. It is a varied hydraulic motor that converts hydraulic pressure into torque to steer the nosewheels. When in the dampening mode, the power unit provides shimmy dampening by pumping fluid through the integral one-way restrictors.

Exercises (407):

1. a. What relay must be deenergized if we are to energize the power transformer in the nose gear steering control box?

b. How is the above relay normally energized?

c. In what position must the landing gear control handle be in if we are to operate the nose gear steering system?

2. What units receive power from the power supply?

3. The command potentiometer is effective for how many degrees of travel?

4. What condition would the selector valve be in when relay K1 is energized?

5. When the aircraft is in flight, what prevents the selector valve, in the nose gear steering system, from being actuated?

408. Point out the general operating principles of the nose gear steering system.

Operation. The nose gear steering system is an electrically controlled hydraulically actuated system that provides directional control of the aircraft during ground operations. When the nose gear steering system is energized, steering is controlled by forward or aft rudder pedal movements relayed electrically to the hydraulic actuating system. When the system is deenergized, the nosewheel is free to turn so the steering system can perform a second function: shimmy dampening.

The nose gear steering switch on the forward or aft control stick grip, as shown in figure 1-3, must be held depressed to energize the nose gear steering system. Movement of the rudder pedals controls the direction and travel of the nose gear steering assembly.

The only time that the nose gear system can be energized is when the nose gear is down and locked and the main landing gear struts are compressed. Movement of the rudder pedals, in either direction, controls output voltage of the nose gear steering command potentiometer. This, then, is applied to a differential amplifier in the nose gear steering control box. (Reference foldout 2 and fig. 1-4.) The output of the differential amplifier determines which coil will receive more current in the nose gear steering servo valve.

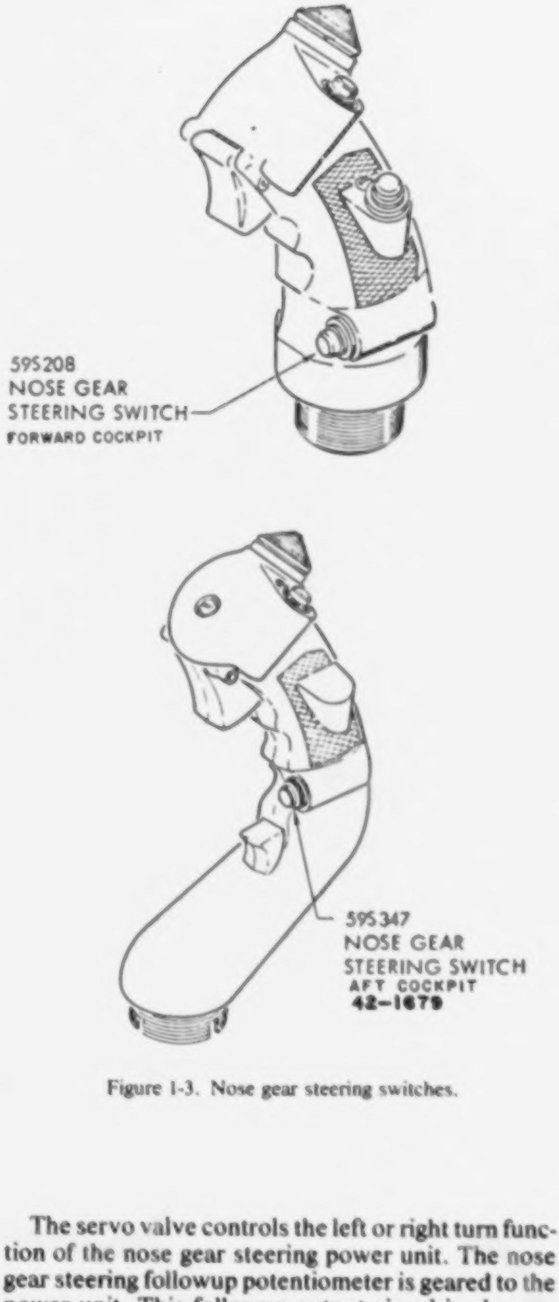


Figure 1-3. Nose gear steering switches.

The servo valve controls the left or right turn function of the nose gear steering power unit. The nose gear steering followup potentiometer is geared to the power unit. This followup output signal is also applied to the differential amplifier. If an error signal exists between the output of the followup and command potentiometers, the differential amplifier will produce a differential current. This current is sent to the servo valve, which then directs hydraulic flow to the vane motor in the nose gear steering power unit. The vane motor turns the nosewheels in the desired direction to reduce the error signal.

As the outputs of the two potentiometers become equal, the error signal is reduced. Then the differential amplifier reduces differential current to stop the wheels at the desired angle of turn. Should an open or a short occur in one of the inputs to the control box, the failure detection network detects the failure. After it detects the failure, it will then remove hydraulic pressure from the steering system. There is a slight time delay before the failure network functions. Once the cause for failure is removed, or goes away, the system may be recycled and normal operation resumed.

Exercises (408):

1. The nose gear steering system provides directional control of the aircraft during ground operation:
   a. When the nose gear steering system is energized, what determines steering direction?

   b. The item identified in "a" above controls the movement of which electrical component?

   c. The signal that "b" above produces is less than applied to what item? Which is located where?

   d. Current from the item identified in "c" above passes thru a coil, which is located where?

2. Dependent on which rudder pedal is depressed, the servo determines the left or right turn function of the nosegear steering power unit:
   a. On making a turn, what potentiometer is geared to the power unit?

   b. The output of the potentiometer identified in "a" above is applied to what?

   c. Since the aircraft is turning, what type of signal is produced?

   d. The signal identified in "c" above comes from a difference of output between what two components?

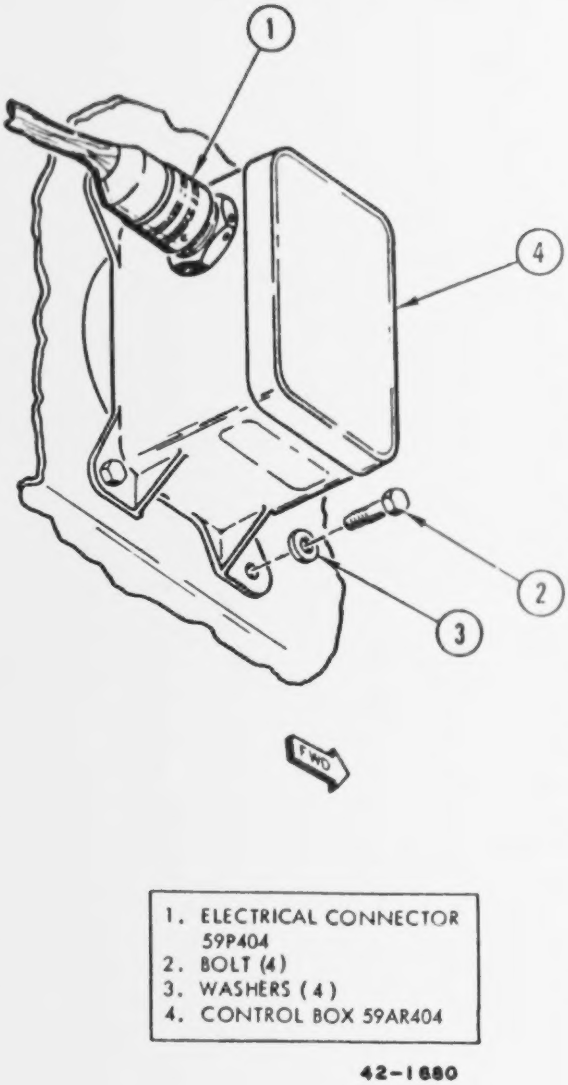
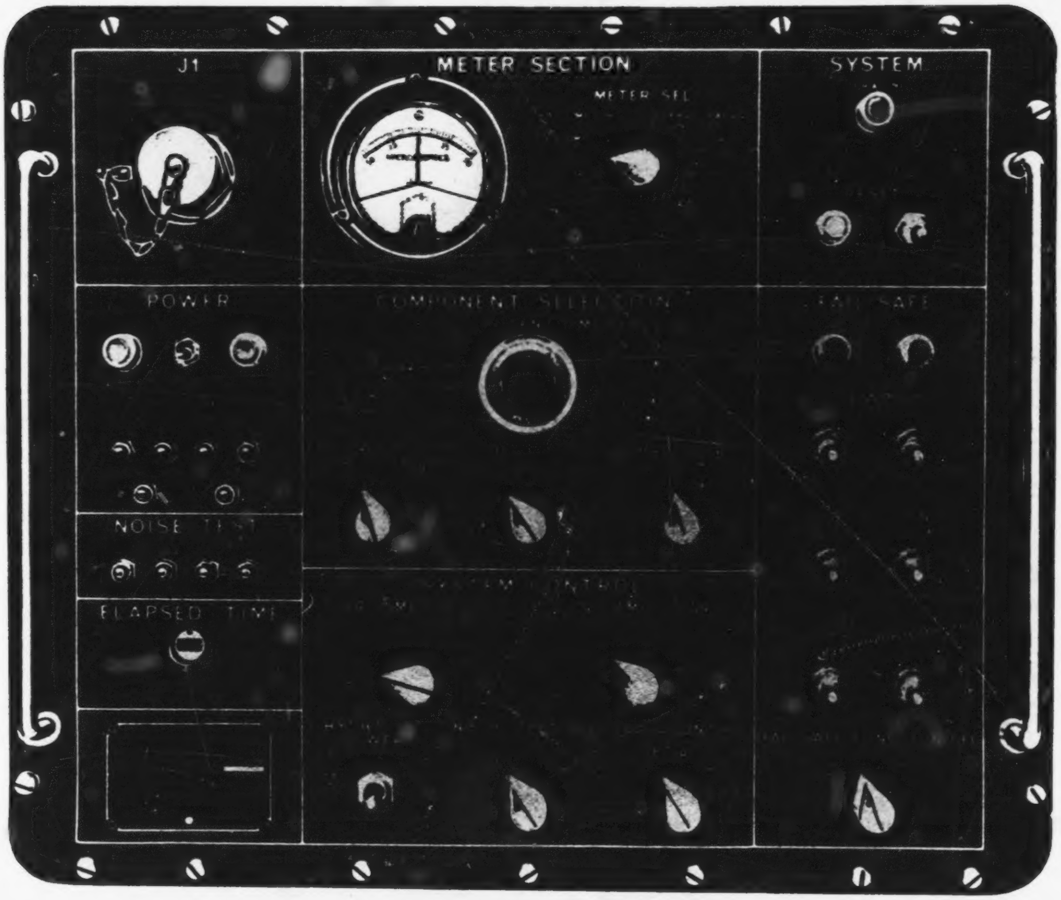


Figure 1-4. Nose gear steering control box.

   e. The current from the components identified in "d" causes the differential amplifier to produce what?

   f. The output produced in "e" above is sent to the servo valve which then directs what to flow, and where?

   g. Once the nosewheels establish their turn position, what happens to the error signal?



42–1678

Figure 1-5. Nose gear steering test set — AN/AJM–20.

409. Identify facts and procedures for inspecting and troubleshooting the nosewheel steering system.

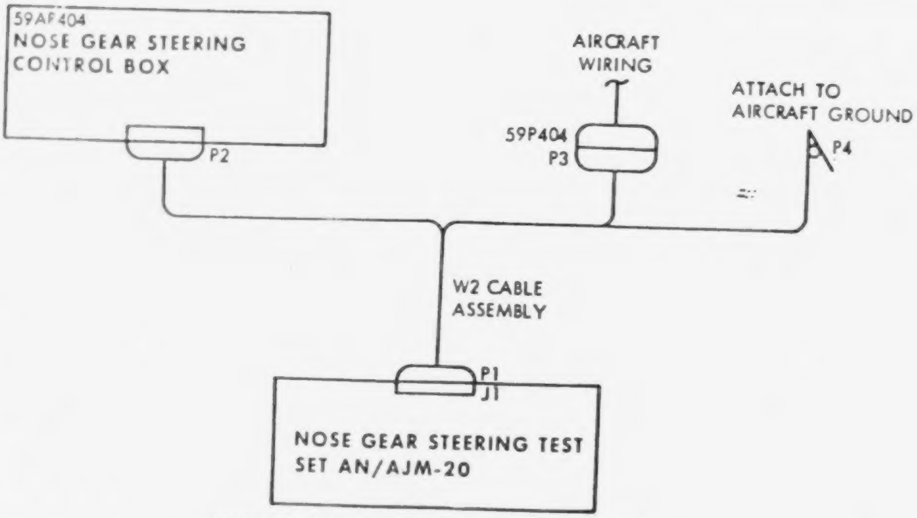
Inspection. When inspecting the nose gear steering system, you should check for signs of wire deterioration, loose components, binding of wires, and security of wires. Make sure all connector plugs are secure on the components and that the components themselves are securely mounted. In places where safety wire is to be used, make sure it is properly installed.

On all phased inspections, you have inspection workcards to follow. These cards contain each item that is required to be inspected during that particular inspection. As long as you follow the workcards, you should have no problems with an inspection and the nose gear steering system should consistently operate trouble-free.

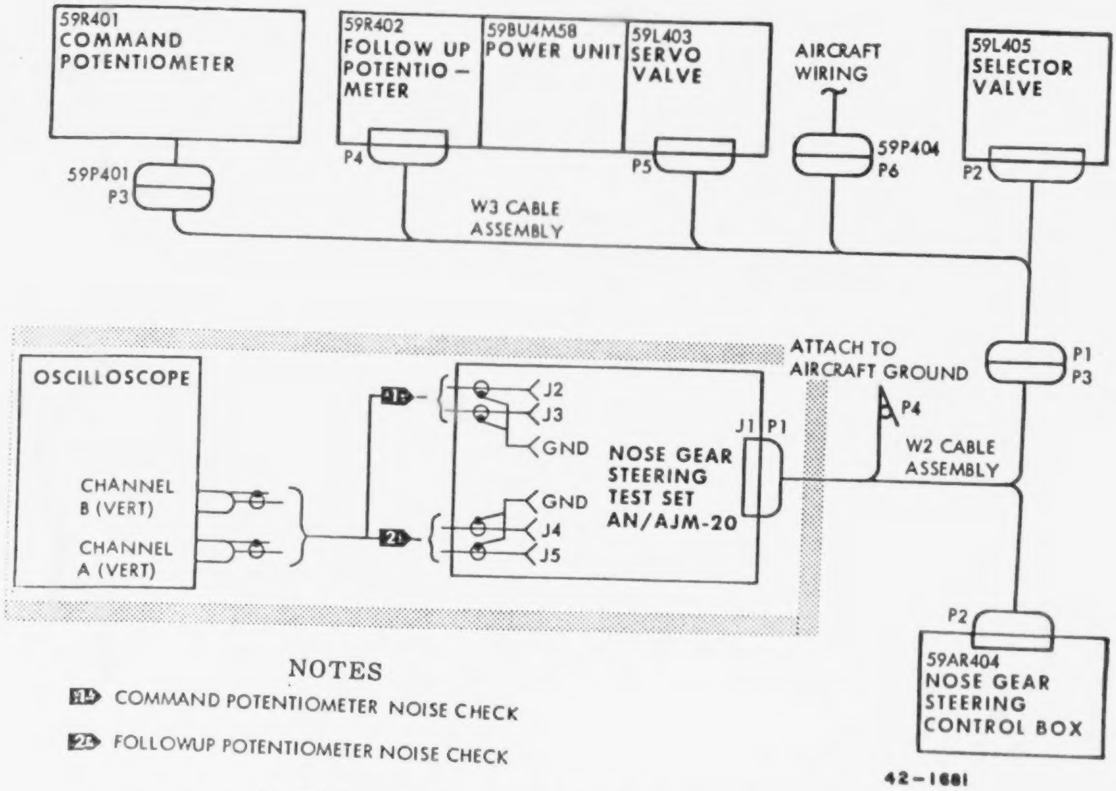
Troubleshooting. Troubleshooting is a skill that must be learned, and the best way to learn it is through practice. But regardless of your knowledge of the nose gear steering system, troubleshooting must be done with the aid of current technical data. Even though some jobs are done time after time and you have the procedure down perfect, you still must use the technical order. It is possible that a change or modification was made to the system that affected the troubleshooting procedures. If you do not follow the exact procedure, you could damage the system.

To aid you in troubleshooting this system, an AN/AJM–20 test set (see fig. 1-5) is used along with an oscilloscope, a power source, a hydraulic power source, a stopwatch, a 4-inch rigging pin, a torque wrench, and a centering template. Naturally the electricians will not be the only specialist required to perform this operation. As an example, you will need a hydraulic specialist to operate the test stand that applies hydraulic pressure to the aircraft.

Figure 1-6 shows the two methods of connecting the test set to the nose gear steering. The oscilloscope, in the lower section of figure 1-6, is used while making a noise check to determine if the potentiometers are in good opoerating condition.


59AF404
NOSE GEAR STEERING CONTROL BOX
P2
AIRCRAFT WIRING
59P404
P3
ATTACH TO AIRCRAFT GROUND
P4
W2 CABLE ASSEMBLY
P1
J1
NOSE GEAR STEERING TEST SET AN/AJM-20

FUNCTIONAL CHECKOUT HOOKUP


59R401
COMMAND POTENTIOMETER
59P401
P3
59R402
FOLLOW UP POTENTIO – METER
P4
59BU4M58
POWER UNIT
59L403
SERVO VALVE
P5
AIRCRAFT WIRING
59P404
P6
59L405
SELECTOR VALVE
P2
W3 CABLE ASSEMBLY
ATTACH TO AIRCRAFT GROUND
P4
P1
P3
W2 CABLE ASSEMBLY
OSCILLOSCOPE
CHANNEL B (VERT)
CHANNEL A (VERT)
1
2
J2
J3
GND
GND
J4
J5
J1 P1
NOSE GEAR STEERING TEST SET AN/AJM-20
P2
59AR404
NOSE GEAR STEERING CONTROL BOX
42-1681

NOTES

1 COMMAND POTENTIOMETER NOISE CHECK

2 FOLLOWUP POTENTIOMETER NOISE CHECK

POTENTIOMETER NOISE CHECKOUT HOOKUP

Figure 1-6. Potentiometer noise checkout hookup.

After the connector plugs of the test set are hooked up, the power unit connected, and hydraulic pressure applied, the troubleshooting procedure may be performed. Note, prior to the above, the nose gear rigging pin should have been installed and the upper torque link should have been separated from the torque collar.

Refer to figure 1-5 as we discuss the preliminary settings of the test set. Test potentiometer control to 500 and lock down. Place all remaining test switches in either the down or counterclockwise position.

In the cockpit, make sure all the nose gear steering circuit breakers are in, then apply power. Test the press-to-test lights on the tester to see that they are operating. Then place the RESET switch up just long enough to see that the OPERATING light comes on, then place it back down. If the OPERATING light does not come on, you have a defective nose gear steering control box.

The above are preliminary settings. We will now explain the procedure to follow to check the amplifier gain.

Position the FOLLOW-UP POT, the INPUT POT, and the SERVO VALVE switch, all to the SIMULATED position. (Reference fig. 1-5 and foldout 2.) Now rotate the CONT AMPL GAIN switch clockwise through all positions and note the meter indication for each phase. If they do not meet the following tolerances for each position, the control box must be replaced.

Switch Position	*Required Indication*
NEUTRAL	0μa ± 2μa
4% RIGHT	20μa ± 4μa
4% LEFT	−20μa ± 4μa
50% RIGHT	20μa ± 4μa
50% LEFT	−20μa ± 4μa
70 DEG LEFT NULL	0μa ± 8μa

When this is completed, return the CONT AMPL GAIN switch to the NEUTRAL position and place the METER SEL switch to the OFF position. This completes the test for amplifier gain.

Now let's see how the tester is hooked up with the oscilloscope to test the potentiometer. We call this a noise test. This is not because we can hear noise in the system, but that it would give us erratic operation of the nose gear steering. The test set is connected as previously noted, i.e., on the lower section of figure 1-6.

The command potentiometer has a unique function and wiper characteristic which must not be confused as a component malfunction within limits defined. Apparent wiper resistance noise characteristics (noise trace) of command potentiometers fall into three basic categories designated as Type I, Type II and Type III. Type I potentiometers (generally but not exclusively) have serial numbers below 1092; Type II potentiometers (generally but not exclusively) have serial numbers 1092 thru 3699; Type III potentiometers (generally but not exclusively) have serial numbers 3700 and up. Noise trace of Type I potentiometers has distinct "hills" or "waves" around neutral (center third). Noise trace of a Type II potentiometer has a smooth "loaf" or "dome" trace around neutral. Noise trace of a Type III potentiometer is similar to trace for a Type II potentiometer except with shallow trace around neutral. These traces are symmetrical and repeatable to distinguish them from random and component malfunction noise spikes. The height of the seven hills shall not exceed 375 mv (ohms), the loaf 450 mv (ohms) and the two hills 160 mv (ohms); other noise such as sudden excursion in excess of 100 mv is unacceptable. In addition, the command potentiometer has a nonlinear function with a very small resistance change around neutral (center third). The command and followup potentiometers have shorting bars at each end of the resistor element with opens in lieu of mechanical stops. The command and followup potentiometers (see figs. 1-7 and 1-8) also have a 500 ohm (nominal) series resistance in the wiper circuit. For a noise diagram of the command and followup potentiometer display on the oscilloscope, see figure 1-9.

Preliminary settings for the noise test are as follows (reference fig. 1-5): the FOLLOW-UP POT to the SIMULATED position; the INPUT POT in the TEST position; the TEST CONTROL switch in the NOISE position; the NOISE TEST SEL switch to the FOLLOW-UP POT NOISE position; the METER SEL switch in the OFF position; the SERVO VALVE switch in the AIRCRAFT position; the RATIOMETER SEL switch in the OFF position; the CONT AMPL GAIN switch in the NEUTRAL position; and the HYDRAULIC POWER switch ON.

The oscilloscope must be adjusted to monitor 100 mv AC spikes. The test set can now be turned on. To make sure the control box is OK, move the RESET switch up until the OPERATING lamp comes on and then release it. If the lamp does not come on, the control box is defective, and must be replaced. After the control box has been replaced, adjust the TEST POTENTIOMETER so that you have a torque collar rotation rate of 3.4 to 4 rpm (15 to 17.6 seconds per revolution). Make sure the potentiometer is locked down. Observe the oscilloscope for spikes (see fig. 1-9). If any spikes are above 100 mv, the potentiometer must be replace.

The use of the troubleshooting charts located in most technical orders can save you a lot of time. They list a defect, then tell you where and/or how to check to make sure that the item is defective, and how to repair or replace it. It may give you several places to check, should one or more of the checks be OK.

After you have determined what the trouble is, the next step would be to repair it. The repair could con-

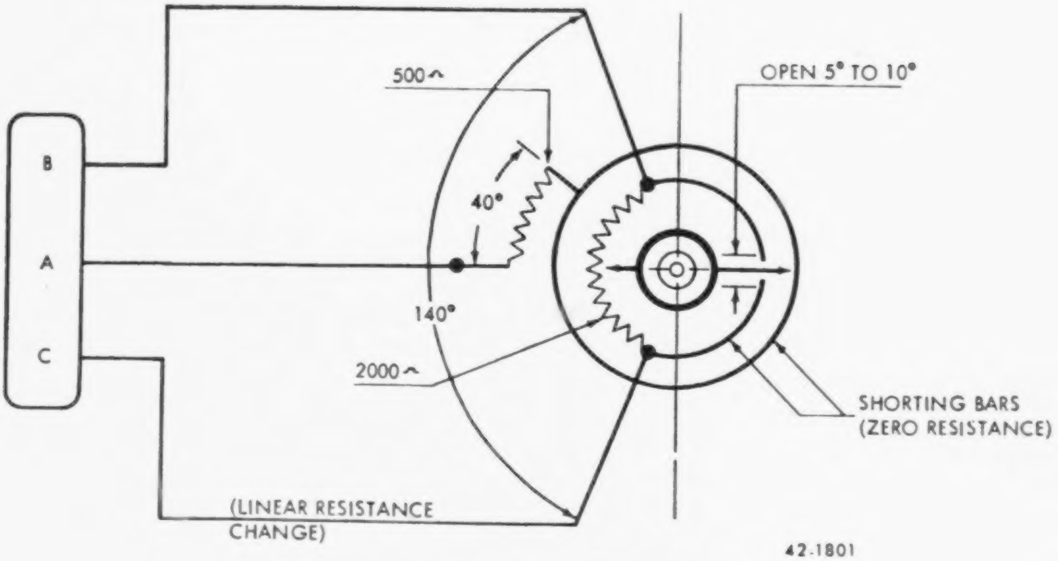

500 Ω
OPEN 5° TO 10°
B
40°
A
140°
C
2000 Ω
SHORTING BARS
(ZERO RESISTANCE)
(LINEAR RESISTANCE
CHANGE)
42-1801

Figure 1-7. Command potentiometer schematic.

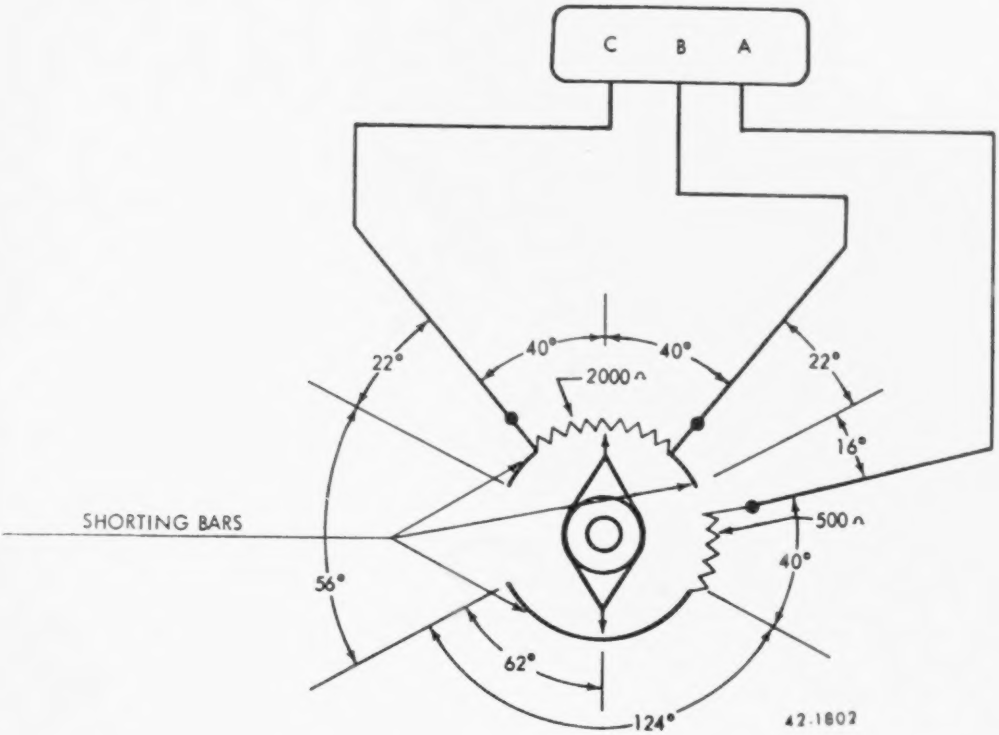

C B A
22°
40°
40°
22°
2000 Ω
16°
SHORTING BARS
500 Ω
56°
40°
62°
124°
42-1802

Figure 1-8. Followup potentiometer schematic.

NOTE

THE FOLLOWING ARE TRUE POTENTIOMETER CHARACTERISTICS AND NOT MALFUNCTIONS WITHIN THE DEFINED LIMITS.

TYPE I POTENTIOMETERS DISPLAY SEVEN "HILLS" OR "WAVES" IN APPROXIMATELY THE CENTER ONE THIRD (1/3) OF POTENTIOMETER STROKE. THE HEIGHT OF "HILLS" OR "WAVES" SHALL NOT EXCEED 375±MV.

TYPE II POTENTIOMETERS DISPLAY A "LOAD" OR "DOME" IN APPROXIMATELY THE CENTER ONE THIRD (1/3) OF POTENTIOMETER STROKE. THE HEIGHT OF "LOAD" OR "DOME" SHALL NOT EXCEED 450 MV.

TYPE III POTENTIOMETER DISPLAY TWO "HILLS", ONE NEAR THE START AND ONE NEAR THE END OF POTENTIOMETER STROKE.

POTENTIOMETERS DISPLAYING ANY SUDDEN EXCURSION IN EXCESS OF 100 MV WILL NOT BE ACCEPTABLE.

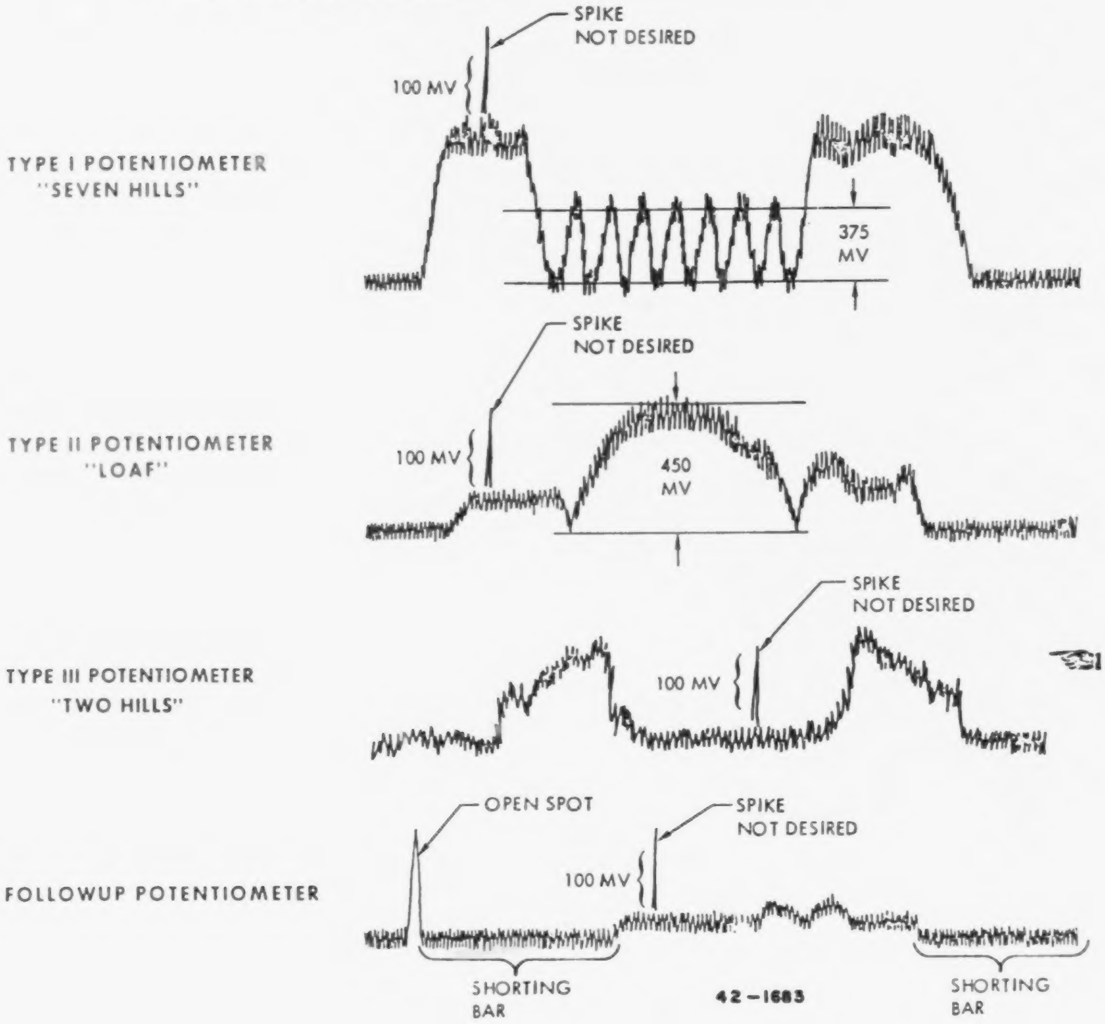


Figure 1-9. Potentiometer noise graphs on oscilloscope.

sist of repairing a broken wire or the replacement of a major component. Whatever the repair may consist of, an operational check must be made before the system can be considered functional. This is done to insure that this was the only thing in the system that had failed and that your repair made the system 100 percent operational.

Exercises (409):

1. When the tester is hooked up with an oscilloscope, you can make a noise test.
   a. This is a test on what component?

   b. Failure of the noise test usually indicates what type of trouble?

2. When the tester is hooked up with an oscilloscope, you can check the nose gear steering control box:
   a. The oscilloscope must be adjusted to monitor what size AC spikes?

   b. When you move the RESET switch up, the OPERATING lamp comes on; then you release the RESET switch. This test indicates what?

3. When the tester is hooked up with an oscilloscope, and the control box has proved OK, the potentiometer can be checked:
   a. The TEST POTENTIOMETER should be adjusted to what?

   b. How many seconds per revolution should be expected?

   c. What oscilloscope indications indicate that the potentiometer must be replaced?

4. Troubleshooting the nosewheel steering system with the AN/AJM−20 nose gear steering test set provided the following data:

	Switch Position	*Actual Indication*
a.	NEUTRAL	−1 μa
b.	4% RIGHT	+25 μa
c.	4% LEFT	−16 μa
d.	50% RIGHT	+25 μa
e.	50% LEFT	−18 μa
f.	70 DEG LEFT NULL	−1 μa

List the alphabetic letters (next to the switch position) that are NOT acceptable.

410. Cite items relative to maintaining the nose gear steering system.

Maintaining the Nose Gear Steering System. To properly maintain the nose gear steering system, you must be familiar with other aspects of the maintenance process. These include the proper installation of components, the bench check and repair of components, and the modification and repair of components.

Installation of components. Anytime a component is replaced, the appropriate technical order must be consulted. If any adjustments to the system are necessary after replacing a component, the technical order provides the answers. It lists torque values and allowable tolerance, as applicable and when required.

A typical example of an installation, taken directly from a technical order, is as follows:

a. Install control box with four washers (3) and bolts (2).

CAUTION

To prevent moisture contamination and corrosion, electrical connector and jack must be inspected for nicks, scratches, and deformation.
Ensure connector is clean, dry and free of damage which would prevent proper mating connection. Ensure placement and serviceability of O-ring (10−90354−19, Bendix Corp.).

b. Inspect electrical connector, jack, and O-ring for nicks, scratches or deformation. Replace defective parts.

c. Apply liberal amount of silicone compound in receptacle for moisture protection, exercising care to avoid excess which would preclude proper connection.

d. Connect electrical connector to control box (4).

e. Perform a detailed operational check per paragraph 3-32.

Bench check and repair of components. The components discussed in this section are mainly of the remove and replace type. As an aircraft electrical systems specialist, about the only testing of any of the system components you wil do will be on the flight line, and with the nose gear steering test set. A typical test set for this system is the AN/AJM−20 test set.

Modification and overhaul of components. If a certain component continues to fail for the same reason, it may indicate that a deficiency exists in the component. Sometimes an inefficient component may require the change of an entire section, or it may only require a minor change within the component. Whatever the reason for this change, the change is classed as a modification. A modification must be approved by the Air Force System Command (AFSC), which will then come back in the form of a TCTO (time compliance technical order). The TCTO specifies when, where, and how the modification is to be accomplished. Modifications are done at either a major repair and overhaul facility for the aircraft, or by you on the flight line. This all depends on the complexity of the work required to perform the modification. All parts to complete the modification are included with the TCTO. An authorized modification would be as far as you could go in changing the system. Overhaul of the nose gear steering electrical components is practically nonexistent. This normally restricts you to the "remove and replace" type of repair to the system.

Exercises (410):

1. When installing components on the nose gear steering system, contamination and corrosion must be watched for:

   a. What consistently and frequently calls the aircraft electrical systems specialists' attention to these factors?

   b. What is the recommended procedure for treating an electrical receptacle to resist moisture?

   c. What is the final technical order requirement after the task has been completed?

2. After installation of a component is completed, what must then be done?

3. How are the components in the nosegear steering tested for operation?

4. Name the test set used with the nose gear steering system.

Flight Controls

FLIGHT CONTROL surfaces are divided into two groups, primary and secondary. The primary control surfaces are comprised of the elevators, rudder, and ailerons. They are constructed like small wings, or airfoils. By changing the shape of the wing, horizontal tail assembly, or vertical tail assembly, they create changes in the lifting forces necessary to produce movement. You might think of the primary control surfaces as those necessary to get the aircraft off the ground, maintain flight, and return to earth.

Secondary flight controls are used to: (1) reduce the force required to actuate the primary control surfaces (2) trim and balance the aircraft in flight, and (3) aid lift by increasing the area of the wings.

This chapter covers the operation and maintenance of the secondary flight controls, including the stabilizer trim, aileron trim, and flap control.

2-1. Stabilizer Trim

Before beginning any maintenance on stabilizer trim (stab trim) circuits, be certain that the control surfaces are not blocked by maintenance stands, tools, etc. Another fact to consider is that you will need to have a helper with you. It would be foolish to attempt to troubleshoot a stab trim circuit by yourself. You would only be asking for an accident.

411. Explain the operation and give the checkout procedures for the C−135 stab trim circuit.

Description. Aircraft stab trim is achieved by: (1) a normal electric power drive, (2) an autopilot drive, or (3) a manual drive. A control switch for the normal electric drive system is on the outboard side of the pilot's and copilot's control wheel. When the normal electric drive is being used, the autopilot position is not in operation. You can see, in figure 2-1, that the autopilot is taken out of the circuit by the auxiliary contacts of the stab trim control relay. A stab trim actuator assembly, which is attached to the leading edge of the stabilizer, includes the electrical actuator unit, the autopilot servo motor, and one normal and one auxiliary screw brake. There is also a disconnect clutch which is operated by the manual system for the purpose of disconnecting the power actuators in the event of actuator jamming or binding. Most of these units are shown in figure 2-1, and 2-2.

The actuator drive unit is capable of moving the stabilizer through its full length of travel. There are limit switches which are used to halt power to the actuator drive unit whenever the stabilizer is 1/2° above, or 14° below the horizontal line. The actuator drive is powered by a 115/200-volt AC trim motor which is controlled by a 28-volt DC circuit. Electrically controlled clutches regulate the direction of the stab trim screw, due to the fact that the motor is nonreversible. The system can be shut off by placing the stab trim cutout switch, on the control stand, to STAB TRIM CUTOUT. This switch can be found in figure 2-1.

A stabilizer safety lock is provided for safety of personnel. This lock is used during any ground maintenance being performed around the area of the stabilizer. The safety lock attaches to the horizontal stab trim control wheel and prevents any movement of the stab trim actuator either electrically or manually.

CAUTION: The pilot's and copilot's horizontal stabilizer control switches should not be actuated in opposite directions while the aircraft is on the ground. This will cause the two clutches to work in opposite directions on the jack screw. The stronger clutch will override the weaker, resulting in excessive wear of the ball detent clutch, or stalling the motor.

Checkout Procedures. The stabilizer trim checkout requires two people. One person performs all operations in the cockpit. The other person acts as an observer in the tail compartment. In order to simplify these instructions, refer to the two people as: person A and person B.

First of all, you must connect electrical power to the airplane as per tech order instructions. Person A checks to see that all stabilizer trim circuit breakers on the main circuit breaker panel are pushed in. Next he checks to see that the stabilizer trim cutout switch on the control stand is in the NORM position.

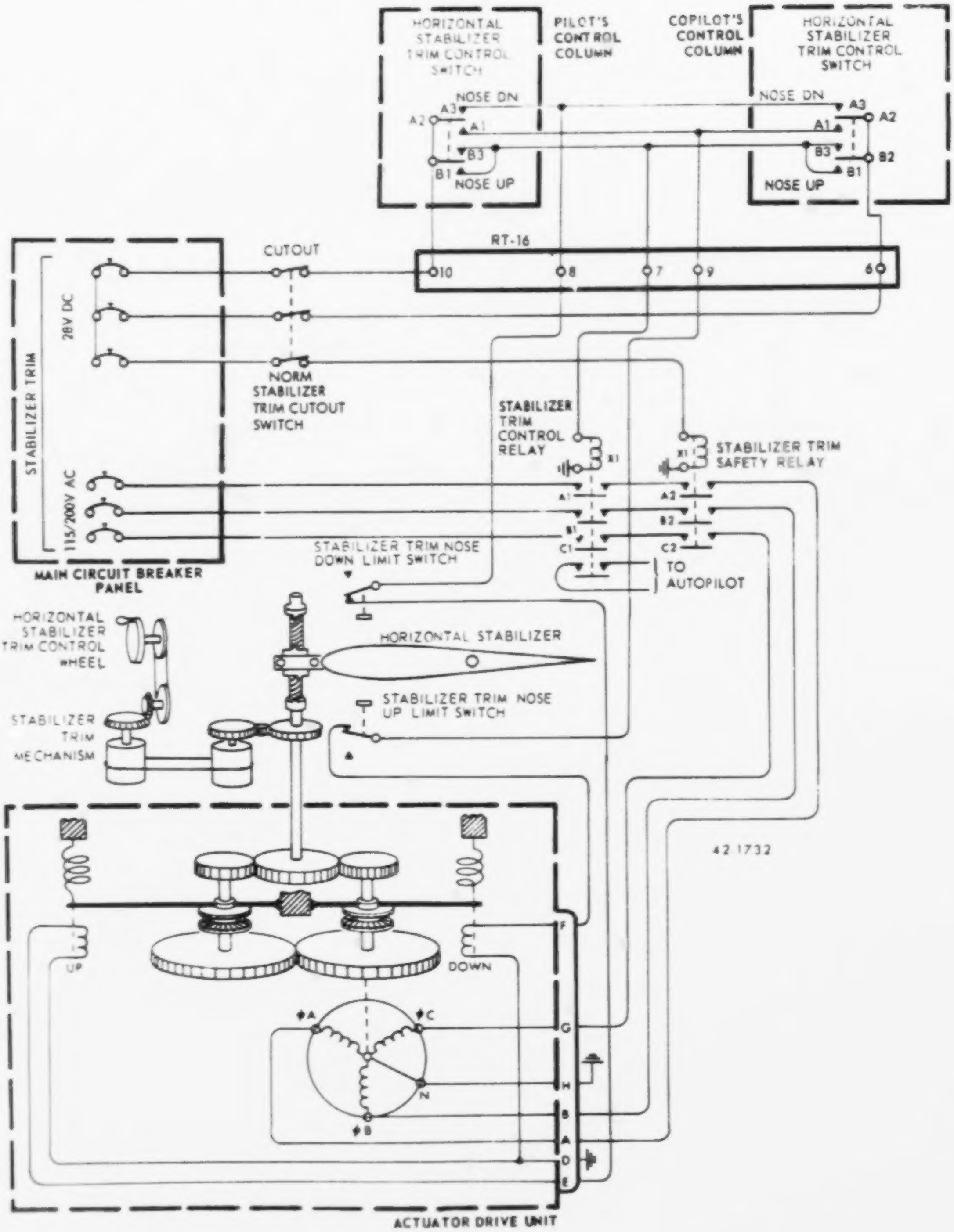

HORIZONTAL STABILIZER TRIM CONTROL SWITCH
PILOT'S CONTROL COLUMN
COPILOT'S CONTROL COLUMN
HORIZONTAL STABILIZER TRIM CONTROL SWITCH
NOSE DN
A3
A2
A1
B3
B1
NOSE UP
NOSE DN
A3
A2
A1
B3
B2
B1
NOSE UP
RT-16
10
8
7
9
6
CUTOUT
28V DC
STABILIZER TRIM
115/200V AC
NORM
STABILIZER TRIM CUTOUT SWITCH
STABILIZER TRIM CONTROL RELAY
X1
A1
B1
C1
STABILIZER TRIM SAFETY RELAY
X1
A2
B2
C2
TO AUTOPILOT
MAIN CIRCUIT BREAKER PANEL
STABILIZER TRIM NOSE DOWN LIMIT SWITCH
HORIZONTAL STABILIZER TRIM CONTROL WHEEL
HORIZONTAL STABILIZER
STABILIZER TRIM NOSE UP LIMIT SWITCH
STABILIZER TRIM MECHANISM
42 1732
UP
DOWN
F
ϕA
ϕC
ϕB
N
G
H
B
A
D
E
ACTUATOR DRIVE UNIT

Figure 2-1. Horizontal stabilizer trim control circuit.

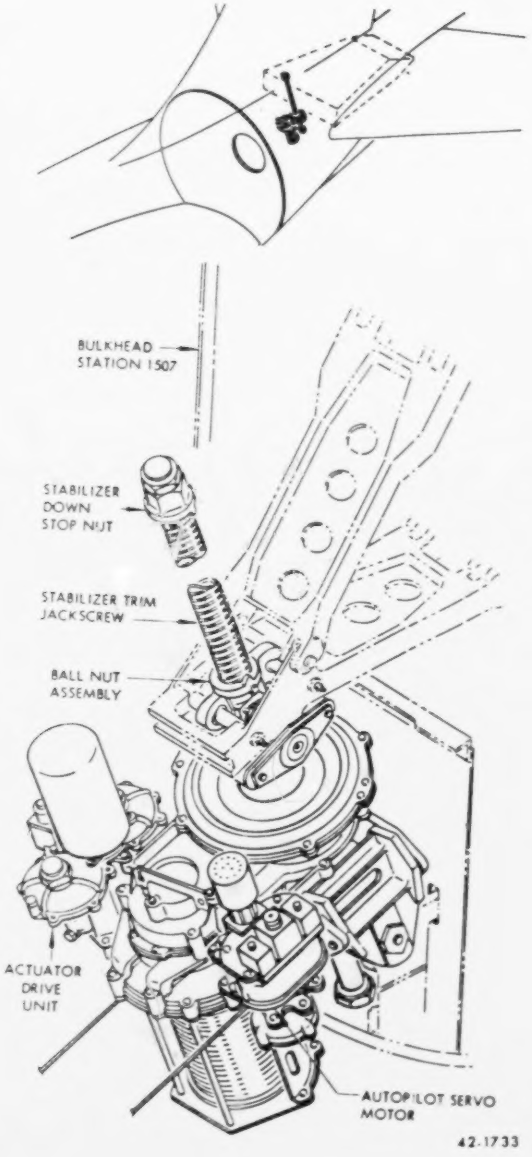


Figure 2-2. Stabilizer trim actuator assembly.

Another CAUTION: Due to the makeup of the stabilizer trim actuator, allow 13 minutes of cooling time for every 2 minutes of actuator operation.

Person A holds the pilot's horizontal stabilizer trim control switch on the pilot's control wheel in the NOSE DN position. (Visible arcing might be noticed in the operation of the trim control switches if the checkout is made under dark conditions. The small arc is normal and has no effect on trim capabilities or switch service life.) Person B checks to see that the leading edge of the horizontal stabilizer moves up. Next, he checks to ensure that the limit switch prevents excessive actuator hammering as the stop nut is contacted and that the clearance between stops does not exceed 3.60 inches as measured along the circumference of the stop nut.

Now, person A holds the pilot's horizontal stabilizer trim control switch on the pilot's control wheel in the NOSE UP position. Check to see that the leading edge of the horizontal stabilizer moves down. Once again person B checks to make sure that the limit switch prevented any excessive actuator hammering as the stop nut is contacted just as he did for the NOSE DN position. He also measures the clearance between stops to assure that the clearance does not exceed 3.60 inches as measured along the circumference of the stop nut.

These same procedures are followed when you check the copilot's horizontal stabilizer trim control switches. When you finish the operational check, return the stabilizer cutout switch to the CUT-OUT position. This concludes the operational check of the stabilizer trim control circuit. You should be able to adapt the information given in this lesson to your work on your particular aircraft.

Exercises (411):

1. What is the purpose of the disconnect clutch?

2. What happens to the circuit when the stabilizer becomes 14° below the horizontal plane?

3. What is used to regulate the direction of the stabilizer trim screw?

4. What would be the result of operating the pilots and copilots trim control switches in the opposite direction?

5. What position should the horizontal stabilizer be in after the control switch is put in the NOSE DN position?

6. How many minutes of actuator cooling time are necessary for 2 minutes of operating time?

7. In what position should you leave the stabilizer cutout switch after the operational check is complete?

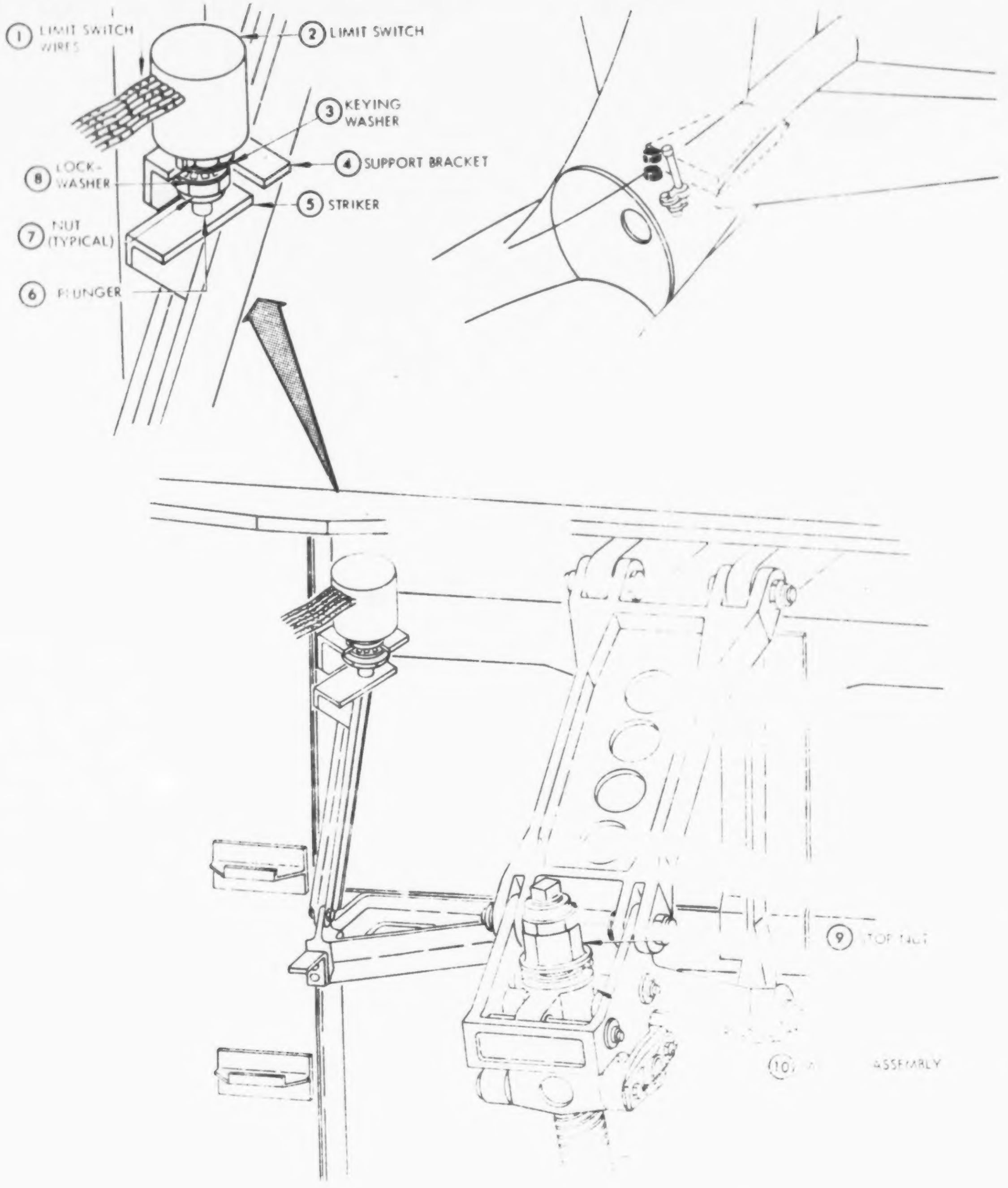

1 LIMIT SWITCH WIRES
2 LIMIT SWITCH
3 KEYING WASHER
4 SUPPORT BRACKET
8 LOCK-WASHER
5 STRIKER
7 NUT (TYPICAL)
6 PLUNGER
9 STOP NUT
10 ASSEMBLY

Figure 2-3. Installation of stabilizer trim limit switch.

412. Cite procedures for installing and adjusting the C–135 stabilizer trim limit switch.

Installing the Stabilizer Trim Limit Switch. Refer to figures 2-3 and 2-4 as you study these procedures.

There are seven individual steps to use when installing the stab trim limit switch. They are listed below as steps *a* through *g*. The call out numbers are found in figure 2-3.

a. Check to assure that the stabilizer safety lock is installed.

b. Install the nut (7) and keying washer (3), on the limit switch (2). The outer tooth of the keying washer should point upwards towards the switch body.

c. Mount the limit switch in the bracket, and install the lockwasher (8) and nut on the plunger side of the switch. (To avoid any possible damage to the limit switch before it is adjusted, install the nut on the switch with a minimum number of threads.)

d. Cut spare wires number 3 and 6 on the limit switch to a length of 12 inches. (NOTE: Switch wire numbers are found on a decal on the base of the switch.) Tape and secure these wires to the existing wire bundle.

e. Wires number 1 and number 4 go to the manual actuator clutch, while wires number 2 and number 5 go to the stabilizer trim control switches.

f. Splice wires 2 and 5 together with wires coming from the stab trim control switches.

g. Splice wires 1 and 4 together with wires coming from the manual actuator clutch. After the splices have been made, wrap the wire bundle and secure it to the aircraft structure.

If you are called upon to install a stab trim switch while you are a "3" level, be sure to have your supervisor check your work while you do the job.

Adjusting the Stabilizer Trim Limit Switch. The adjustment procedures require two people, as it did for the checkout procedures. Once again to simplify instructions, refer to the electrical specialists as person A, and person B. Person A performs all of the operations in the cockpit, while person B is the observer and performs any work required in the tail compartment.

First you must connect external power as per the aircraft TO. Person A will rotate the jackscrew (11 in fig. 2-3) by turning the stab trim control wheel in the direction of travel of the switch to be adjusted. The ball nut assembly (10) should be against the stop nut (9). Person B should now check to see that the jack screw is against the stop nut. One thing you should never do is to actuate the stab trim control switch before the limit switch is adjusted. The ball nut assembly may be damaged if it hits the stop nut too hard.

Person A should now back the ball nut assembly (2 in fig. 2-4) away from the stop nut (1) using the stab trim control wheel until clearance between stops is 3.60 (+0.00/–0.40) inches as measured by person B along the circumference of the stop nut.

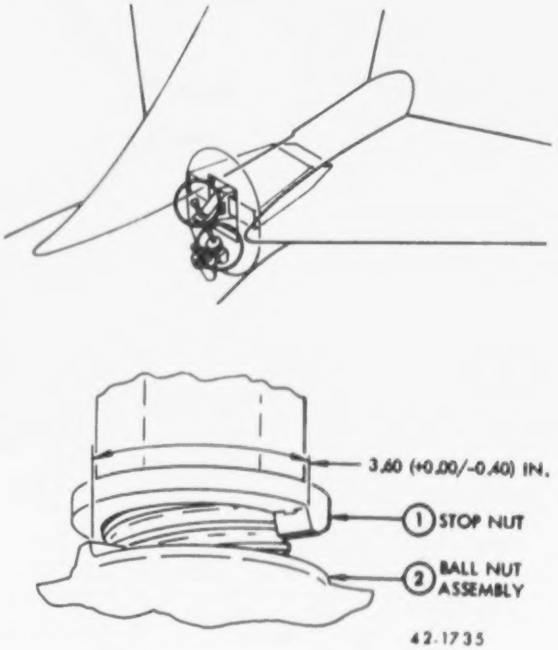


Figure 2-4. Stabilizer trim actuator stops.

Person B should loosen all nuts (7 in fig. 2-3) on the limit switch (2). Adjust the nuts until the switch actuates when it is in contact with the striker (5). A clicking sound is audible when the limit switch is actuated. Tighten all nuts on the switch.

Person A now checks to see that the stab trim cutout switch is in the NORM position. He will back off the ball nut assembly using the pilot's stab trim control switch, and run the system towards full stops at full speed.

Man B must now check to see that the limit switches prevent excessive hammering as each stop nut is contacted, and that the clearance between stops does not exceed 3.60 inches.

If everything checks out according to the TO, safety-wire the nuts on the limit switch after final adjustment.

Excercises (412):

1. In what direction should the outer key of the keying washer point?

2. To what length should you cut spare wires 3 and 6?

3. Which wires splice to the manual actuator clutch wiring?

4. What is the reason for the limit switches in the stabilizer trim circuit?

413. Point out components that could cause malfunctions in the stab trim system.

Troubleshooting Circuit Malfunctions. Troubleshooting components in the stabilizer trim system is usually confined to taking voltage and resistance checks of relays, switches, and actuators. Usually you would not need any specialized equipment; in most cases, a PSM–6 would be adequate.

This section discusses two common stab trim problems, the isolation procedures involved in troubleshooting and the remedy for the trouble.

Trouble No. 1. Let's say that your shop chief sends you out to help in troubleshooting a stab trim circuit as a result of a write up. The pilot's write up states that there was no trim action from either his or the copilot's stab control switch.

What does this tell you? Well, for one thing, you know that the problem probably isn't in the stab control trim switches. Looking at figure 2-1, try and figure out what else could cause it. How about the stab trim control relay? Check for 115 VAC at terminals A1, B1, C1, A2, B2 and C2 of the relay. If there is voltage at A1, B1, and C, but nothing at A2, B2 or C2, then the relay must be defective. Next, check the stabilizer trim cutout switch. An easy way to check this is to check for 28 VDC at terminal X1 of the stab trim safety relay. Replace the switch if there is no voltage present. If everything on down the line checks OK according to the TO, then you will eventually get to the actuator. To check the actuator, first remove the electrical plug. Then, check for 115 VAC between terminals A and H, B and H, and G and H. Of course you can see that H is the ground side of the actuator. (Don't forget a voltage reading here will indicate an open ground.) If there is voltage and a good ground available, then the actuator is probably defective.

Trouble No. 2. This write up states that the stabilizer does not move down when either stabilizer trim control switch is put to the NOSE UP position. Of course, this could be a bad actuator, and should be checked as per instructions in the paragraph above. If the actuator does check OK, then you will probably find that the up limit switch is defective. To check this, you must once again remove the electrical plug from the actuator drive unit and test for voltage, (28 VDC), at pin "F" when the trim control switch is actuated. You should replace the limit switch if the voltage is not present.

By studying figure 2-1, you should be able to troubleshoot any defect in the circuit without too much trouble. You will need this figure in answering the questions in the following exercises.

Exercises (413):

1. What component would be defective if you found that there is no voltage at terminal B1 of the pilot's stab trim control switch?

2. What position would the stab trim cutout switch be in to deactivate the stab trim safety relay?

3. You find that you have voltage at terminal #8 on terminal board RT–16, but none on the up side of the actuator drive unit. What component is most likely defective?

4. A voltage reading at pin H of the actuator drive unit should tell you what?

414. Give information pertinent to bench checking a stabilizer trim actuator.

When to Bench Check the Actuators. The need to bench check a stabilizer trim actuator should be obvious to you. You should bench check it before you install it on the aircraft. Another time you might bench check one would be to determine if the stabilizer trim actuator that you suspect to be bad is bad, or if there could be a problem on the aircraft such as wiring, switches etc. If you know that a certain aircraft was going to have a trim actuator change on the next inspection, you would want to make sure that the actuator was bench checked and found to be serviceable before installation. It is very embarrassing to install an actuator, without first bench checking it, only to have it malfunction on the aircraft.

How to Bench Check the Actuator. The "how" part of bench checking an actuator varies with the actuator. Be sure and use the appropriate tech order when performing bench check procedures.

In most cases, the shop you are assigned to will have provisions set up for actuator bench check. This is usually a local manufactured tester made to tech order specifications. If for some reason your shop does not have facilities for bench check in the shop, you should use a modified version of the following check, done on the aircraft.

The check is performed to assure satisfactory operation of the system. First, however, consider the precautions you should observe when operating a stabilizer trim circuit.

Because this system incorporates a hydraulic brake mechanism that is easily overheated, do not operate the system more than four full cycles during a 15-minute period. If it is necessary to operate the system continuously, limit the operation to two full cycles, followed by a 7-minute cooling period. Another precaution you should observe is that there must be sufficient hydraulic pressure to operate the stabilizer mechanism. The typical system discussed in this section operates at a minimum flow of 12 gpm at 3000 psi.

It is not good practice to trim the stabilizer into the full NOSE UP or NOSE DN position electrically. Instead, trim the stabilizer into these extreme positions manually by using the manual trim wheel located in the cockpit. Naturally, you should also avoid moving one trim switch into the NOSE UP position while the other trim switch is applying a NOSE DN signal.

The total range of travel of a typical stabilizer is around 13°. The neutral or 0° position must be adjusted so that less than half of the travel is available for NOSE UP trim (stabilizer leading edge down), and the remainder for NOSE DN trim (stabilizer leading edge up). If the proper range of travel is not available, you must have the cable adjustment checked. Always check the technical order for the aircraft you are working on to determine the correct limits of travel. Now, let's see how the operational check is performed.

The operational check is started by placing the stabilizer trim cutout switch (fig. 2-1) in the NORMAL position. Next, move one of the two stabilizer trim switches to the 0° position. The stabilizer's leading edge should be in the 0° position, as indicated by the decal on the side of the fuselage. To check proper movement of the stabilizer, move the other trim switch to the NOSE UP position to trim for a short distance. The stablizer's leading edge should move down, and the trim indicator should show the correct movement. When the trim switch is moved to the NOSE DN position, the stabilizer's leading edge should move up and the trim indicator should show the correct movement.

The next part of the operational check is to determine the proper operation of the cutout circuits. This is performed with the trim wheel in the 0° posi- and the stabilizer trim cutout switch (see fig. 2-1) in the CUTOUT position. When each trim switch is moved to the NOSE UP or NOSE DN position, there should be no movement of either the stabilizer or the manual trim wheel.

The final part of the operational check is to make sure that the drive chain of the manual trim wheel does not slip its sprockets. To accomplish this step of the operational check, place the cutout switch in NORMAL and engage one of the stabilizer trim switches. While the trim wheel is turning, grasp it by hand and try to stop it from turning. If the drive chain slips the sprockets, it must be adjusted.

When you have completed the operational check, trim the stabilizer back to the 0° position with either trim switch.

Exercises (414):

1. What should you do to a trim actuator before you install it on the aircraft?

2. In what way can bench checking an actuator help in troubleshooting?

3. How do the electric shops usually get their stabilizer trim bench check equipment?

4. How much cooling period is needed if you have operated the trim actuator for two full cycles?

5. How should the range of travel of a trim actuator be divided?

6. Which way should the leading edge of the stabilizer move with the trim switch in the NOSE DN position?

415. Cite maintenance procedures used when replacing the C–135 control column wire bundle.

Occasionally, as an aircraft electrician, you have to replace the control column wire bundle. For instance, this task may be necessary to satisfy a modification project or during an overhaul or repair condition. You will see, as you study this material, that the stabilizer trim switch is but one of the switches attached to the wire bundle.

Replacing the Control Column Wire Bundle. There are many steps in this job that have to be completed by personnel from the aero-repair shop. Before the electrician can begin work, the dust cover must be removed, rigging pins must be installed, the control column supported, etc. After all the other maintenance personnel have completed their part of the job, you can begin yours.

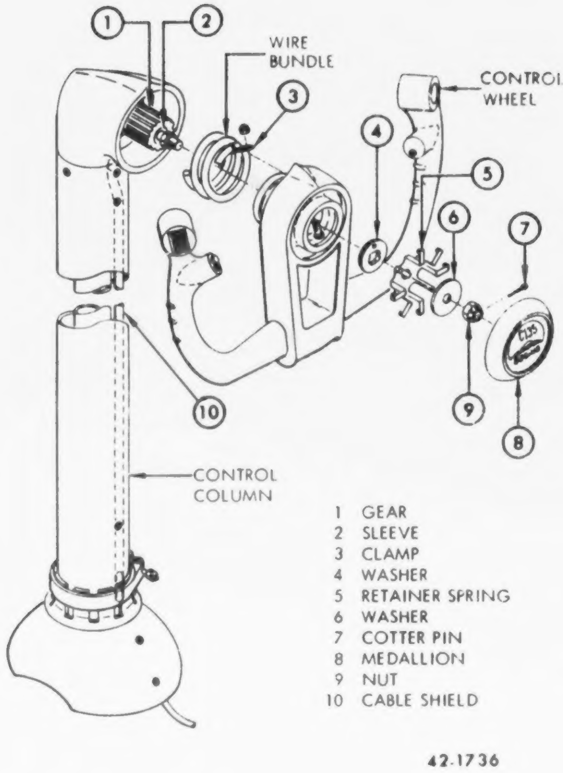

1
2
WIRE BUNDLE
3
CONTROL WHEEL
4
5
6
7
10
9
8
CONTROL COLUMN
1 GEAR
2 SLEEVE
3 CLAMP
4 WASHER
5 RETAINER SPRING
6 WASHER
7 COTTER PIN
8 MEDALLION
9 NUT
10 CABLE SHIELD
42.1736

Figure 2-5. Installation of control column wire bundle.

The first thing you must do is to remove the medallion (8, in fig. 2-5) from the control wheel by pulling it straight out. Remove the cotter pin (7), nut (9), washer (6), retainer spring, (5), and washer (4) from the control wheel hub. Remember that you are working in a very critical foreign object damage (FOD.) area due to the cockpit environment, and that you must be FOD. conscience at all times.

Install the nut (9) and turn it finger tight against the square-shouldered sleeve (2) in the hub. Next, you should scribe an index mark on the sleeve (2), on the gear (1) around the sleeve, and on the control wheel. You will find that this is a very necessary step that will aid you in replacing the control wheel. Now you are ready to remove the control wheel. Do this by pulling the wheel straight out. After that, loosen the cable clamp (3) in the control wheel hub. With this done, you can disconnect the leads from the switches in the control wheel and pull the wire bundle out of the control wheel.

At this point, it might be a good idea to pull an inspection on the new wire bundle you are about to install, as well as to the control column in which it will go. Look for such things as cut or nicked wires, sharp objects that could damage the cable, as well as the condition of the clamps. You will find that a thorough inspection now could save you much distress later on.

Thread the new wire bundle down through the cable shield tube (10) in the control column from the hub of the control column. Install, but do not tighten, the two clamps in the base of the control column.

Now you are ready to thread the new wire bundle through the left spoke of the control wheel, and out the rim to the switch locations. Pull the leads out through the appropriate switch openings. Crimp or solder terminal lugs to the screw leads for the autopilot disengage and interphone-mike switches. These switches are shown in figure 2-6. Connect the jumpers to the interphone-mike switch (5) and to the stabilizer trim switch (1), if they are not already installed. Strip the insulation from the jumper for the interphone-mike switch and slide a teflon sleeve over the wire. Crimp or solder terminal lugs to the wire. The distance between the jumpered terminals should be 0.75 to 0.81 inch. If you are using a stabilizer trim switch manufactured by the Mason company, part number 426206, you should know that it already has an internal jumper from terminals A2 to B2, and does not need an external jumper. If you do need to make up jumpers, make them from No. 20 wire.

Connect the leads to the switches (1, 5, and 7) and install the switches in the wheel. Once again, you can find these switches in figure 2-6.

Now, install the cable clamp in the control wheel hub. REMEMBER: Leave enough slack cable in the wheel to allow the switches to be replaced.

Allow 19.5 inches of cable between the cable clamp in the control wheel and the opening in the

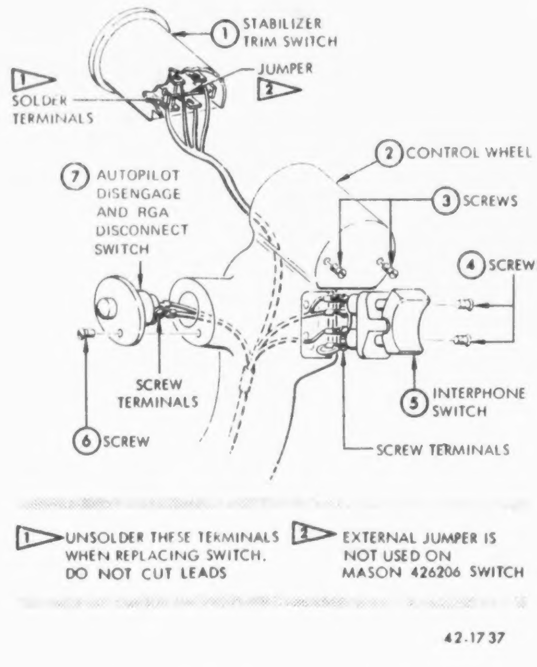

1 STABILIZER TRIM SWITCH
JUMPER
2
1
SOLDER TERMINALS
2 CONTROL WHEEL
7 AUTOPILOT DISENGAGE AND RGA DISCONNECT SWITCH
3 SCREWS
4 SCREWS
SCREW TERMINALS
5 INTERPHONE SWITCH
6 SCREW
SCREW TERMINALS
1 UNSOLDER THESE TERMINALS WHEN REPLACING SWITCH. DO NOT CUT LEADS
2 EXTERNAL JUMPER IS NOT USED ON MASON 426206 SWITCH
42.1737

Figure 2-6. Installation of control wheel switches.

control column housing. This is enough for three turns around the control wheel hub. These turns are made counterclockwise around the hub when viewed from the pilot's seat with the control columns installed.

Tighten the cable clamps in the base of the control column. Check to see that the length of wire below the control column is 43.5 inches (pilot's control column) or 21.5 inches (copilot's control column). This measurement is taken from the lower cable clamp in the dust cover to the end of the longest wire in the cable. Wrap the wire around the hub and carefully install the control wheel. Keep the index marks that you scribed on the sleeve, gear, and control wheel aligned. Remove the nut from the hub bolt (that's the one you installed finger tight earlier).

Install the washers, spring, nut, and cotter pin onto the control wheel. Don't forget to put the medallion back in place.

You will probably have to have Aero Repair do their part of the job before it can be operationally checked, so be sure you have done your part right! Have your supervisor check your work before the control column is reinstalled. Of course, the new wire bundle and switches will have to be operationally checked before the job can be signed off.

This concludes our lesson on stabilizer trim. You probably know by now that there are other trim circuits. There is a rudder trim circuit, an aileron trim circuit, and probably others. The information presented in this section can be adapted for the other trim circuits, which are not discussed in this CDC.

Exercises (415):

1. What should you always remember to do when working in the cockpit?

2. At what point in the operation should you place a scribe mark on the sleeve and gear?

3. What maintenance procedure should you perform before installing the new wire bundle?

4. Does the stabilizer switch, number 426206, need an external jumper?

5. At what point in the job should you have your supervisor check your work?

2-2. Aileron Trim

The aileron trim control circuit is provided to assist the pilot and copilot in maintaining the level flight attitude of the aircraft. The aileron trim circuit on light aircraft has the same job to do for the pilot as does the lateral trim control on heavy aircraft. Of course, the way it is done is very different, since some heavy aircraft do not have ailerons; instead, spoilers on the top of the wing are used to gain the same effect.

416. Give the purpose of selected components in a typical aileron trim control circuit.

Components. The circuit consists of an aileron trim actuator, two trim switches, trim selector switch, and takeoff trim indicator lights. This circuit is powered by DC. Refer to figure 2-7 for the electrical circuits and components during the following discussion of the aileron trim control.

Trim switches and takeoff trim indicator lights. The control stick grip trim switch is used as the normal means of control. An auxiliary trim switch is used as an emergency means of controlling the aileron trim control circuit. The trim selector switch is provided to permit selection of the control stick grip trim switch or the auxiliary trim switch for control of the circuit. The takeoff trim indicator lights are used to indicate when the ailerons are in the takeoff trim position. An indicator light test switch is provided to check the indicator light bulbs, regardless of the aileron trim position. Blocking rectifiers are used to prevent feedback current from passing to the deenergized side of the circuit.

Trim motor. The aileron trim motor is a DC split-field motor containing two limit switches and a takeoff indicator light switch. The motor is provided to drive the left and right aileron trim actuators, and it is controlled from the cockpit by a trim switch on the top of the control stick grip, or by a switch located on the trim panel.

Trim actuator. The aileron trim actuators are provided to produce a mechanical followup linkage for normal control of the ailerons and to permit electrical trim of the ailerons by extending or retracting the mechanical linkage between each aileron and the power control assembly. The trim actuators are gear-driven jackscrews which are attached to and driven by the trim motor, through flexible drive shafts.

Exercises (416):

1. What component is used as the normal means of aileron trim control?

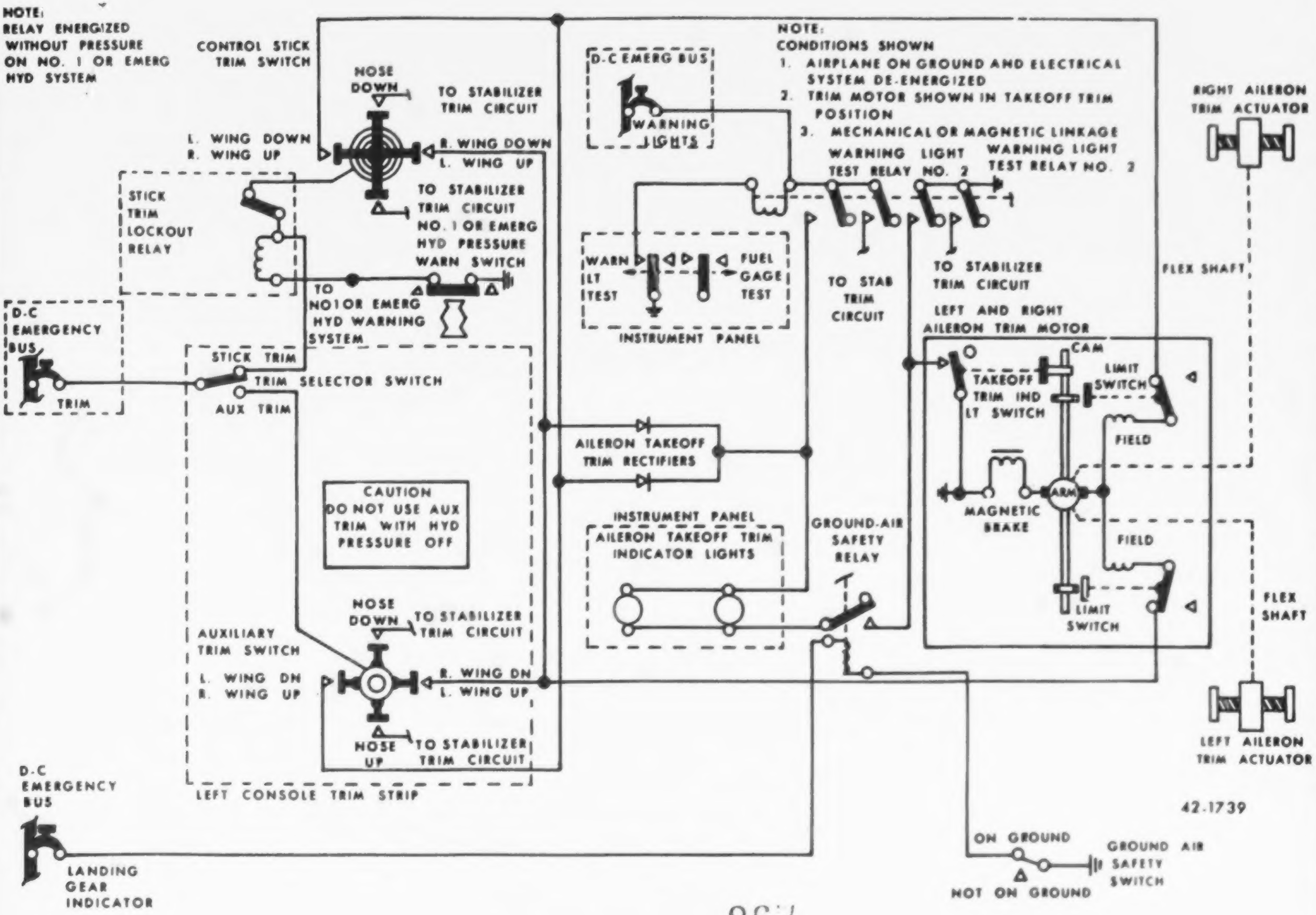

NOTE:
RELAY ENERGIZED WITHOUT PRESSURE ON NO. 1 OR EMERG HYD SYSTEM
CONTROL STICK TRIM SWITCH
NOSE DOWN
TO STABILIZER TRIM CIRCUIT
L. WING DOWN
R. WING UP
R. WING DOWN
L. WING UP
TO STABILIZER TRIM CIRCUIT
NO. 1 OR EMERG HYD PRESSURE WARN SWITCH
STICK TRIM LOCKOUT RELAY
TO NO 1 OR EMERG HYD WARNING SYSTEM
D-C EMERGENCY BUS
TRIM
STICK TRIM
TRIM SELECTOR SWITCH
AUX TRIM
CAUTION
DO NOT USE AUX TRIM WITH HYD PRESSURE OFF
AUXILIARY TRIM SWITCH
NOSE DOWN
TO STABILIZER TRIM CIRCUIT
L. WING DN
R. WING UP
R. WING DN
L. WING UP
NOSE UP
TO STABILIZER TRIM CIRCUIT
LEFT CONSOLE TRIM STRIP
D-C EMERGENCY BUS
LANDING GEAR INDICATOR
D-C EMERG BUS
WARNING LIGHTS
NOTE:
CONDITIONS SHOWN
1. AIRPLANE ON GROUND AND ELECTRICAL SYSTEM DE-ENERGIZED
2. TRIM MOTOR SHOWN IN TAKEOFF TRIM POSITION
3. MECHANICAL OR MAGNETIC LINKAGE
WARNING LIGHT TEST RELAY NO. 2
WARNING LIGHT TEST RELAY NO. 2
WARN LT TEST
FUEL GAGE TEST
INSTRUMENT PANEL
TO STAB TRIM CIRCUIT
TO STABILIZER TRIM CIRCUIT
LEFT AND RIGHT AILERON TRIM MOTOR
AILERON TAKEOFF TRIM RECTIFIERS
CAM
TAKEOFF TRIM IND LT SWITCH
LIMIT SWITCH
FIELD
MAGNETIC BRAKE
ARM
FIELD
LIMIT SWITCH
INSTRUMENT PANEL
AILERON TAKEOFF TRIM INDICATOR LIGHTS
GROUND-AIR SAFETY RELAY
RIGHT AILERON TRIM ACTUATOR
FLEX SHAFT
FLEX SHAFT
LEFT AILERON TRIM ACTUATOR
42-1739
ON GROUND
NOT ON GROUND
GROUND AIR SAFETY SWITCH

Figure 2-7. Aileron trim control circuits.

2. What component tells the pilot when the ailerons are in the take off position?

3. What is used to control the aileron trim motor?

4. Which component is driven by the trim motor?

417. Cite operational features of the aileron trim control circuit.

Operational Features. With the trim selector switch in the STICK TRIM position, toggling the thumb-actuated control stick grip trim switch to the left energizes the trim motor through one limit switch. The motor operates in the direction required to give a left aileron up, right aileron down (left wing down, right wing up) deflection of the ailerons. The motor will continue to run in this direction until stopped by removal of the thumb from the grip control switch, or by the trim motor limit switch (see fig. 2-7).

With the trim motor operating in a direction calling for left aileron up, right aileron down deflection, the left trim actuator jackscrew begins to retract, and the right trim actuator jackscrew begins to extend. The left servo valve assembly linkage arm is moved in a direction to shift its dual spool valve in one direction while the right servo valve assembly linkage arm is moved in a direction to shift its dual spool valve in the opposite direction. The right and left dual spool valves direct hydraulic flow and pressure to the ailerons, which, in turn, will cause the left aileron to deflect upward and the right aileron to deflect downward. This action will continue until the trim control switch is released or until the maximum aileron trim deflection is obtained.

Regardless of the degree of aileron deflection through the trim control system, the control stick position will be the same as it was when the trim was initiated. Toggling the thumb-actuated control stick grip trim switch to the right will produce exactly the same operation, but in the opposite directions.

With the aircraft on the ground, the electrical system energized, and the hydraulic systems under pressure, the takeoff trim indicator lights can be energized either through the takeoff trim indicator light switch within the trim motor or by the WARN LT TEST switch (see fig. 2-7).

Normal operation through the motor switch occurs whenever the trim motor is run through the takeoff trim position of the ailerons and the trim control is actuated. The indicator will not remain on after the trim control switch is released. To establish the takeoff trim position of the ailerons, select either left or right trim with the control stick grip trim switch, and hold it until the trim indicator light momentarily flashes on, then off. Immediately release the switch, then toggle it for the opposite trim, but in small increments, until the indicator light flashes on. Immediately release the switch, and the ailerons will be in the takeoff trim position.

To test the takeoff trim indicator lights, select the WARN LT TEST position of the test switch. This provides an alternate source of power from the DC emergency bus, energizing a warning light relay which directs power to the takeoff trim indicator lights. The ground side of the lights then passes through the ground-air safety relay switch contacts (closed with the aircraft on the ground and electrical power on), then to ground through the warning light relay switch contacts.

The lights cannot operate once the aircraft is airborne, due to the landing-gear-actuated ground-air safety switch. This prevents the lights from disturbing the pilot's vision when inflight trim of the aircraft is required.

Now go back and trace the circuit of each split field in the motor and of the takeoff trim indicator lights to their respective power supply.

Exercises (417):

1. What two switches can cause the aileron trim motor to stop running?

2. What is the purpose of the right and left dual spool valves?

3. Will the control stick move when trim is initiated?

4. How long will the indicator light remain on after the trim switch is released?

5. In what position are the ground-air safety relay switch contacts with the aircraft on the ground and power on?

6. Can the takeoff trim indicator lights operate with the aircraft airborne?

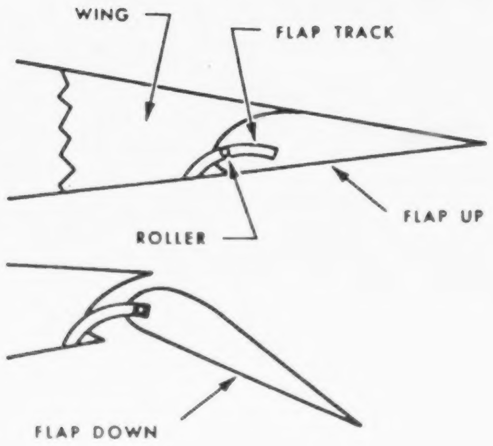


Figure 2-8. Slotted flap.

418. Name the precautions that should be taken and give procedures to follow when performing an operational check on a typical aileron trim control circuit.

Precautions. There are certain precautions that should be observed during this operational check. The aileron trim system should not be operated unless power is supplied to both the electrical hydraulic systems. Without this power, damage may result to the trim actuator motor and the flex shaft. Before turning on the ground power supply, all the switches and controls should be checked and moved to the GROUND position, and all the control surfaces should be clear of obstructions. Read the applicable TO to learn the various precautions involved in this system's operation.

Operational Check. With all the preparations and precautions for the operational check completed and the power supplies connected, the AILERON TAKEOFF TRIM indicator lights should not be illuminated if the control stick is in the neutral position. When the maximum aileron travel is obtained by holding the control stick trim control switch, the AILERON TAKEOFF TRIM indicator lights should flash. The maximum aileron travel and flashing of the AILERON TAKEOFF TRIM indicator lights should be checked for movement in both directions. The left aileron and right aileron should travel so many degrees, one up and the other down, and adjustment should be made if the travel of each is out of tolerance according to the applicable TO.

Exercises (418):

1. What two systems must be supplied with power before the system is operated?

2. In what position should all switches and controls be placed before system operation?

3. What position should the left aileron be in if the right one is down?

2-3. Flap Systems

The aircraft flap system, whether it is used on a large or small airplane, has the same job to perform. It is used to control lift and drag of the wing, to provide for shortened takeoffs, and to reduce landing speeds. This sections covers two types of flaps and leading edge slats. Also, some maintenance aspects of the (flap) system are discussed.

419. Point out significant operational features of the flap system.

Wing Flaps. Wing flaps are comparatively large airfoils. They are hinged at the trailing edge of the aircraft wings inboard of the ailerons. They serve to increase the gliding angle of the aircraft without increasing the speed. This permits the aircraft to dive or glide at a steeper angle and at a lower speed than would otherwise be possible. By increasing the lift effect, the landing and takeoff roll is shortened. This allows the aircraft to operate from shorter runways or to operate with a higher gross weight. Some wing flaps are hydraulically operated with an electrical control. Others are electrically operated and controlled. Cables or pushrods may be used for actuating the flaps or for synchronizing them. The maximum flap angle is usually 45° or less.

Several types of wing flaps are used on modern aircraft. The two types of flaps used on heavy aircraft are slotted and Fowler.

Slotted flaps. The slotted type rolls back and down on tracks. This flap is mounted on specially designed hinges or on rollers which run on a track. The flap moves downward and rearward from the main portion of the wing (see fig. 2-8) to form a "slot" between the flap and the wing. The "slot" thus opened allows a flow of air over the upper surface of the flap. The airflow eliminates some undesirable stall characteristics.

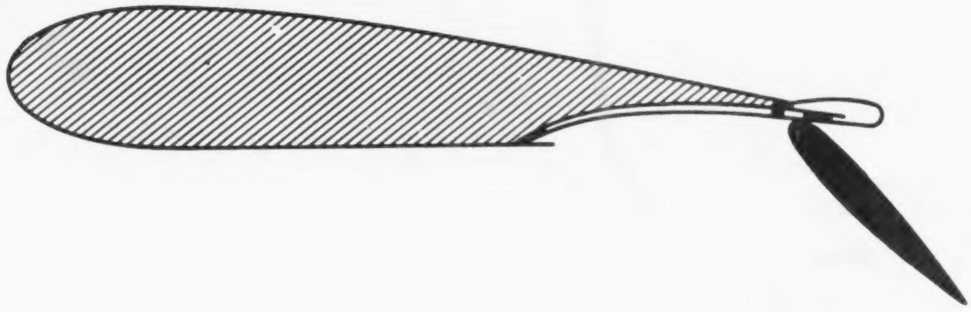


Figure 2-9. Fowler flap.

Fowler flap. The Fowler flap is the type which has the lower surface of the trailing edge of the wing rolling back on tracks (see fig. 2-9). This movement increases the effective width of the wing and lowers the trailing edge to about 40° below its retracted (UP) position. Fowler flaps are generally used on bomber and cargo type aircraft.

Leading Edge Slats. These, or similar devices, are used mainly on fighter type aircraft to automatically reduce the stall characteristics. However, a few of the large, heavy weight aircraft also use leading edge slats. Figure 2-10 shows the leading edge slat extended forward and downward, which increases the camber or curvature of the wing, which increases lift. During low-speed operation when high light is required, the combination of these slats and trailing edge flap generates more lift than is actually required for takeoff. In addition these systems, with proper engine and elevator control, present the wing at a suitable angle of attack for safe landing.

Leading-Edge and Trailing-Edge Wing Flaps. These flaps are electrically interconnected by a control circuit and mechanically interconnected by flexible drive shafts. A set of switches actuated by a single lever in the cockpit controls the flaps. The leading-edge-flap control circuit components are shown on figure 2-11 and consist of a flap actuator, a flap power relay, an H-BOX, a flap control switch, circuit breakers and a flap lock motor assembly. The leading-edge flap control circuit has a flap lock motor assembly; otherwise, the components of this circuit and of the trailing edge are the same. Since both control circuits are identical, we shall discuss only one—that is, the leading-edge flap control circuit. Keep in mind that both sets of wing flaps are used for takeoffs and landings.

Operation of Leading-Edge Flap Control Circuit. When the flap control is placed in the TAKEOFF (T.O.) position, DC power is applied through the WING FLAP CONTROL SWITCH to the closed contacts of the energized FLAP CONTROL BUS TRANSFER RELAY, and then to the LEADING EDGE FLAP TAKEOFF CONTROL RELAY, as illustrated on figure 2-11. The TAKEOFF CONTROL RELAY energizes and DC power is then connected through the RETRACT LIMIT SWITCH of the left leading-edge flap lock actuator motor to the UNLOCKED FIELD of the motor. The motor then begins to operate the jackscrews. (These jackscrews do not move the flaps.) The retraction of the jackscrews pulls the cables to the flap lock assemblies, disengaging the locking hooks and arming (closing) the LEFT and RIGHT FLAP LOCK CONTROL SWITCHES.

When the actuator jackscrews reach the fully retracted position, the motor RETRACT LIMIT SWITCH opens the motor circuit and the FLAP LOCK MOTOR stops rotating. Also, the motor RETRACT LIMIT SWITCH directs DC power through the contacts (unlock position) of the FLAP LOCK CONTROL SWITCHES and through the contacts of the TAKEOFF CONTROL RELAY to the TAKEOFF LIMIT SWITCH (DN) in the H-BOX. The DC power from the DOWN LIMIT SWITCH energizes the MAGNETIC BRAKE inside the H-BOX. The magnetic brake then releases the flap actuator jackscrews (not those operated by the flap lock motor). At the same time, DC power from the DOWN LIMIT SWITCH energizes the LEADING-EDGE FLAP POWER DN RELAY.

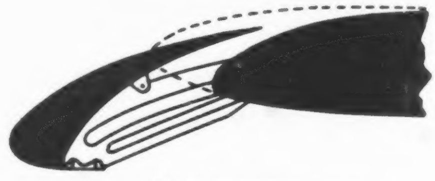


Figure 2-10. Cross sectional view — slat extended.

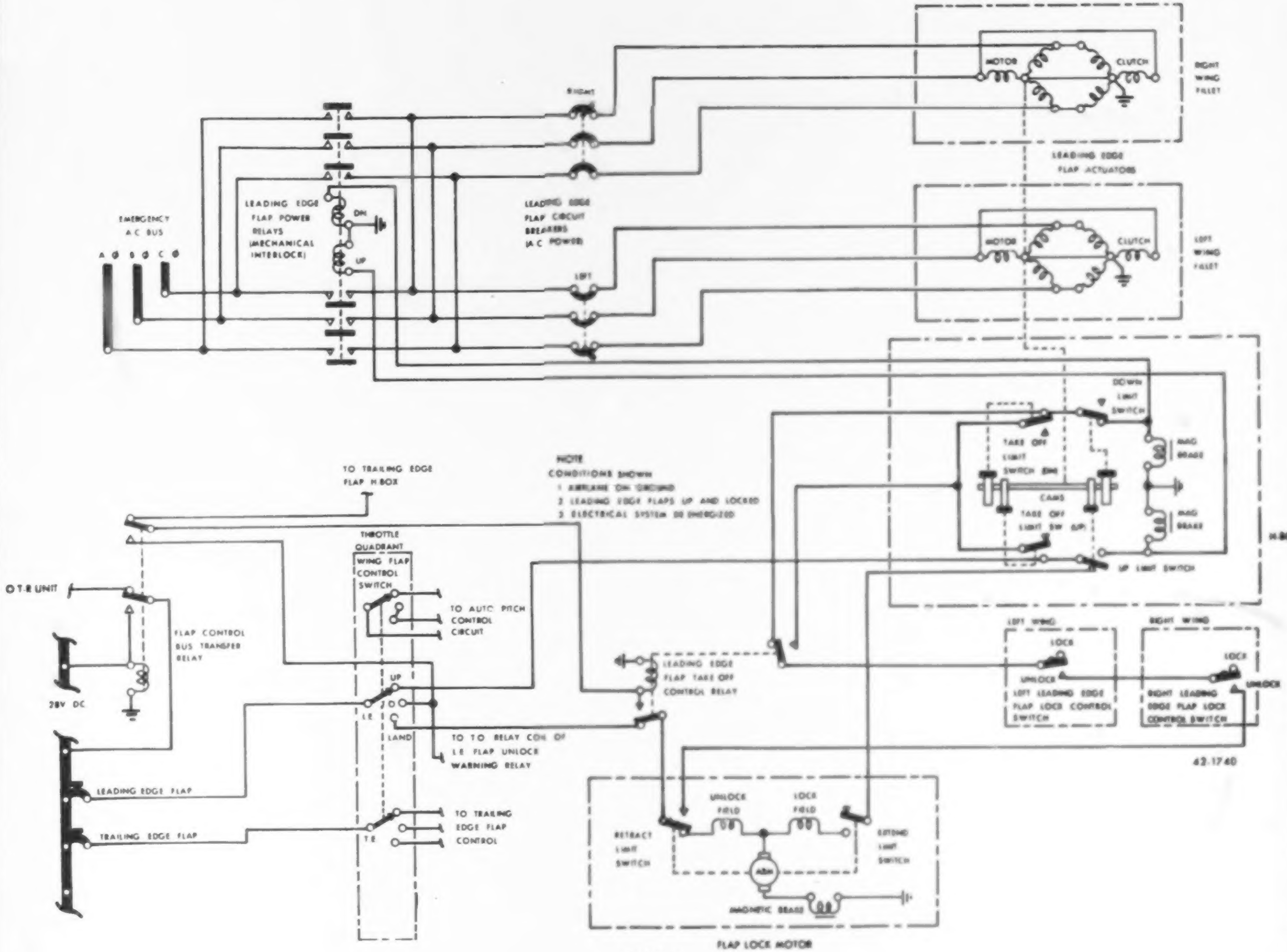

RIGHT
LEADING EDGE FLAP CIRCUIT BREAKERS (A C POWER)
LEFT
EMERGENCY A C BUS
A Ø
B Ø
C Ø
LEADING EDGE FLAP POWER RELAYS (MECHANICAL INTERLOCK)
DN
UP
MOTOR
CLUTCH
RIGHT WING FILLET
LEADING EDGE FLAP ACTUATORS
MOTOR
CLUTCH
LEFT WING FILLET
DOWN LIMIT SWITCH
TAKE OFF LIMIT SWITCH (DN)
MAG BRAKE
CAMS
TAKE OFF LIMIT SW (UP)
MAG BRAKE
UP LIMIT SWITCH
H-BOX
NOTE
CONDITIONS SHOWN
1 AIRPLANE ON GROUND
2 LEADING EDGE FLAPS UP AND LOCKED
3 ELECTRICAL SYSTEM DE-ENERGIZED
TO TRAILING EDGE FLAP H-BOX
THROTTLE QUADRANT
WING FLAP CONTROL SWITCH
TO AUTO PITCH CONTROL CIRCUIT
O-T-R UNIT
FLAP CONTROL BUS TRANSFER RELAY
28V DC
UP
T O
L E
LAND
TO T O RELAY COIL OF L E FLAP UNLOCK WARNING RELAY
LEADING EDGE FLAP
TRAILING EDGE FLAP
T E
TO TRAILING EDGE FLAP CONTROL
LEADING EDGE FLAP TAKE OFF CONTROL RELAY
LEFT WING
LOCK
UNLOCK
LEFT LEADING EDGE FLAP LOCK CONTROL SWITCH
RIGHT WING
LOCK
UNLOCK
RIGHT LEADING EDGE FLAP LOCK CONTROL SWITCH
42-1740
UNLOCK FIELD
LOCK FIELD
RETRACT LIMIT SWITCH
EXTEND LIMIT SWITCH
ADH
MAGNETIC BRAKE
FLAP LOCK MOTOR

Figure 2-11. Wing leading-edge-flap actuator control circuit.

BEST COPY AVAILABLE

The FLAP POWER DN RELAY completes the AC power circuit to the LEFT and RIGHT LEADING EDGE FLAP ACTUATORS. The magnetic clutches in both actuators energize (engage), and the flaps move toward the TAKEOFF position. The actuators operate the flexible drive shafts which rotate the shaft and cam mechanism inside the H-BOX.

When the flaps reach approximately 13° down from the faired (retracted) position, the DOWN LIMIT SWITCH in the H-BOX opens and flaps are stopped. Also, the magnetic brake is engaged, and the magnetic clutch in each actuator is disengaged when DC power is removed by the DOWN LIMIT SWITCH. This permits the brake in the H-BOX to stop flap travel through the jackscrews and the actuator motors coast to a stop. Moving the FLAP CONTROL to the LAND (on some aircraft this is called DOWN) position energizes the DN power relay and actuators. This time the flap travel is limited by the DOWN LIMIT SWITCH in the H-BOX. The flaps are stopped approximately 28° down from the faired position.

Placing the FLAP CONTROL SWITCH in the TAKEOFF (T.O.) position, energizes the UP power relay and the actuators. The phase rotations are reversed in the motors by the UP power relay when the FLAP CONTROL SWITCH is moved from the LAND position (see fig. 2-11). The flaps retract until stopped by the UP TAKEOFF LIMIT SWITCH in the H-BOX. In this case, the flaps are approximately 13° down from the faired position.

Placing the FLAP CONTROL SWITCH in the UP position again energizes the UP power relay and the actuators. Now, the flap travel is limited by the UP LIMIT SWITCH in the H-BOX. The flaps are stopped at the faired position.

Exercises (419):

1. How do wing flaps shorten landing and takeoff roll?

2. Some wing flaps are hydraulically operated with an ________.

3. What are the two types of flaps used on heavy aircraft?

4. What is the function of the slotted flap?

5. Briefly describe the Fowler flap.

6. What service do leading edge slats provide?

420. Give procedures associated with the maintenance of a flap actuator.

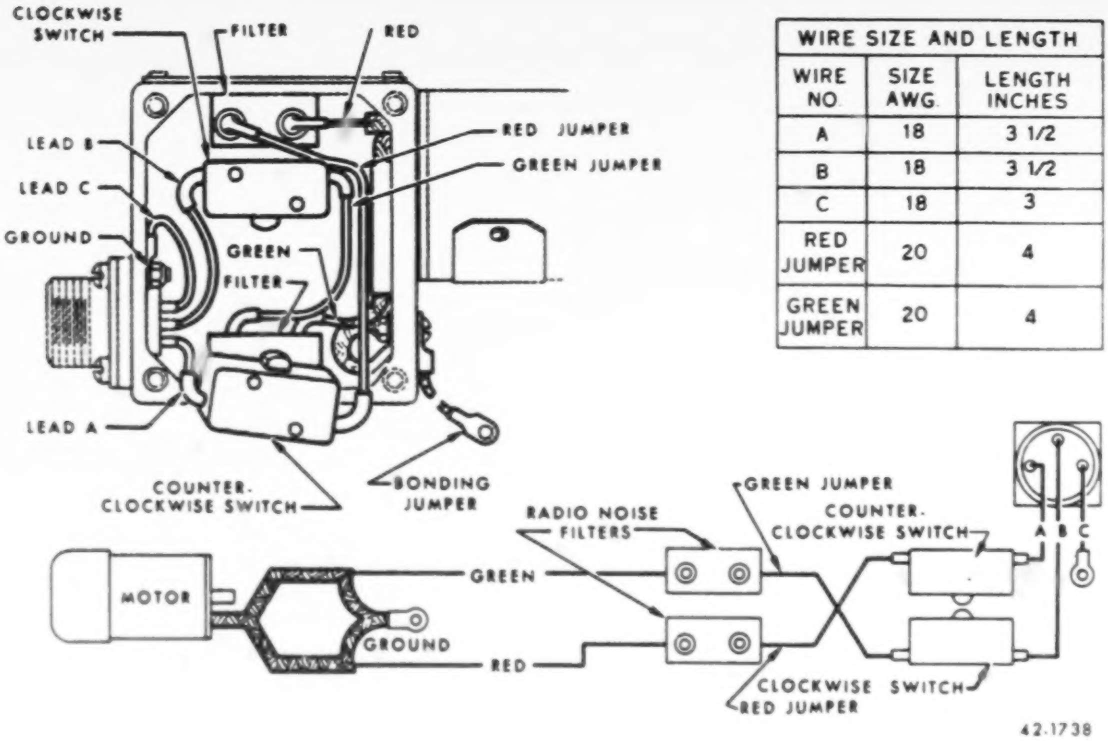
Repair and Overhaul. As you know, an actuator is composed of a motor connected to a gear train that drives a flexible shaft. The motor may be controlled manually or automatically by limit switches. The type of motor determines the capability of the actuator.

Many repair and overhaul parts for actuators are provided in the form of kits. The stock numbers for the repair kits and for the nonkitted parts may be found in S-00-1-1, *Master Cross-Reference Index*. The presence of a new part in a repair or overhaul kit usually eliminates the necessity of cleaning, inspecting, or reworking the equivalent part removed from the assembly that is being repaired. If any part in the kit is to be inspected or tested before installation, instructions for performing these requirements are included. When a part is not normally removed in the process of disassembly and it is serviceable, the part need not be removed solely for the purpose of replacement by a corresponding kitted part. It is important that the applicable technical order for overhaul instructions of an actuator be read and that the instructions be followed carefully. Disassembly and reassembly of actuators should not be performed without the applicable technical order.

Cleaning consists of washing all nonelectrical parts in an approved cleaning solvent. This should be done in a well-ventilated area; otherwise personnel may breathe the funes, which may be toxic. Solvents should not be used in the presence of a fire, since some fumes are flammable.

The wiring diagram of a typical actuator is illustrated in figure 2-12. Notice how the wires are placed and connected to each electrical terminal and component. The chart shown in figure 2-12 lists the size and length of each wire segment inside the actuator. The colored insulation on the wire aids in identifying the wire installed with the wiring on the diagram.

Bench Check. The limit switches may require calibration or adjustment before the actuator is bench tested for serviceability. In some cases the limit switches are set when the actuator is installed on the unit it operates. During a no-load test, the actuator should operate in a satisfactory manner. For example, it should operate without unusual noise, without binding, and without vibration. During a rated-load test, check to be sure that the load cur-


CLOCKWISE SWITCH
FILTER
RED
RED JUMPER
GREEN JUMPER
LEAD B
LEAD C
GROUND
GREEN
FILTER
LEAD A
COUNTER-CLOCKWISE SWITCH
BONDING JUMPER
RADIO NOISE FILTERS
GREEN JUMPER
COUNTER-CLOCKWISE SWITCH
A B C
MOTOR
GREEN
GROUND
RED
CLOCKWISE SWITCH
RED JUMPER
42-1738

WIRE SIZE AND LENGTH		
WIRE NO.	SIZE AWG.	LENGTH INCHES
A	18	3 1/2
B	18	3 1/2
C	18	3
RED JUMPER	20	4
GREEN JUMPER	20	4

Figure 2-12. Cutaway — electrical actuator.

rent does not exceed its limits. Of course, the previously mentioned limit switch adjustments must be done in accordance with the applicable tech order.

Modification. In the event that there is a need for the modification of a flap actuator, the necessary parts will come to you in the form of a kit. If it is an emergency type of modification, all of the aircraft could possibly be grounded until the modification is completed AF wide. If it is of a routine nature, you would probably do them one at a time during aircraft down-for-maintenance time. Of course we cannot discount the fact that it might be an extensive modification that is done at the depot. In that case your shop would probably order actuators that were already modified, and send the old ones back to depot.

Exercises (420):

1. In what form would you usually receive repair or overhaul parts?

2. Do all parts received in an overhaul kit have to be used?

3. What form of instruction must you have before you tear down and reassemble an actuator?

4. Give a very common reason for bench checking an actuator.

5. If an emergency modification had to be completed, how would this affect other similar aircraft?

421. Identify defective components in given circuits within the C–135 flap and spoiler warning systems.

Trouble No. 1. In this first problem, the warning horn fails to sound when the flaps and spoilers are in the incorrect takeoff position.

What should you check first? The first items you should always check are the circuit breakers. Check all circuit breakers that apply to the flap and spoiler warning circuits. These are located on both the main and switched DC bus circuit breaker panel. If any breakers are tripped, reset the tripped one(s) and try the horn again.

The next item to check is the horn itself. To do this, you need to see if 28 volts DC exists between the input terminal and ground of the horn. If the voltage is present, then it is time to replace the horn. If not, troubleshoot the rest of the circuit to find out where the voltage is lost.

It could be that you have a defective flap and spoiler warning throttle limit switch. Remove the wire from the NO (normally open) terminal of the switch. Next, advance No. 3 throttle full forward and check continuity between COM (common), and NO terminal of the throttle limit switch. Replace the limit switch if there is no continuity.

The last item to check for this trouble is the ground safety switch relay. Check for continuity between terminals A1 and A2 of the relay with all the landing gear down and locked and the airplane weight on the gear. Replace the relay if there is no continuity.

Trouble No. 2. The pilot wrote up the warning horn as failing to sound when the flaps were not in the proper position for takeoff (the horn should sound, warning the pilot that his flaps are not in the correct position for takeoff). In this case it did not warn him. The probable cause for this write-up is a defective flap warning switch. To check this, set the No. 3 throttle to the IDLE position. Set the flap control lever to the 00 or 50 detent position. Check for continuity between terminals COM and NC (normally closed) of the flap warning switch. Replace the switch if there is no continuity.

Trouble No. 3. Here you find that the right-hand leading-edge flap light does not come on. Experience tells you that you probably have a bad right-hand leading-edge flap warning switch. Check this by pressing the light to see if it will illuminate. If the light comes on, remove and replace the flap warning switch. If the light does not come on, then the light assembly is probably defective.

Exercises (421):

1. What items should be checked first if the write-up stated that the warning horn failed to operate with the flaps and spoilers in the incorrect takeoff position?

2. If the warning horn is written up as inoperative and there is 28 VDC between input and ground, what component is defective?

3. What component is probably defective if the horn does not sound when the flaps are in any other position other than takeoff?

4. What component is probably defective if one of the leading-edge flap lights fails to come on?

Power Plant, Fuel Control, and Warning Systems

THERE ARE three systems in the aircraft that are very important to the pilot and crew. These systems are: the power plant system; the fuel control system; and the warning systems. You must learn to properly maintain each of these systems.

The power plant section includes the starting and ignition circuits. Therefore, the various methods of starting jet aircraft and the circuits that control these operations are covered in this chapter.

To keep the aircraft running after it is started, fuel must be supplied to the engine. This chapter also discusses how fuel gets from the fuel tanks in the aircraft to the engine.

When the aircraft is operating, there are many things to watch for, and it gets difficult to monitor every indicator constantly. To assist the crew, warning circuits are incorporated to alert them to any serious malfunction. This is done through a series of warning lights. They are: fire warning, overheat warning, takeoff warning, and master warning.

3-1. Power Plant Electrical

The power plant is a very important part of the aircraft—without it, the aircraft would never leave the ground. The more you know about the power plant, the easier your job will be to maintain the systems you are responsible for. We do not intend to make an engine mechanic out of you. However, we wish to give you enough knowledge to help you become an outstanding electrician.

To start an engine, electrical power is required. Both the starter and ignition systems depend on sufficient electrical power at the correct time. Let's see how the control circuits perform this function as well as how the starter and ignition work.

422. Cite operational characteristics of the fuel air starter system.

Operation of the Fuel Air Starter. Many of today's jet aircraft use special starters that operate on both fuel and air, or air alone. This means that the aircraft is not dependent on external sources of air for starting engines. Starters are designed to be used as selfcontained units. They may also be used as conventional pneumatic starters. At this point, let's take a closer look at the fuel-air type starter.

The fuel-air starter is a small jet engine that is used to energize the turbine discs. The starter burns jet fuel in an integral combustion section and utilizes the energy released in combustion to drive a turbine. The latter, through a gear reduction clutch arrangement, drives an output shaft. The unit is designed to produce the torque required to accelerate a turbojet or turboprop engine from zero rpm to a speed of 2300–2500 rpm within a given time.

The starter is mounted on the engine so that the output shaft engages the engine starter drive. Fuel is taken from the engine supply; electricity for ignition and control components is supplied by the aircraft electrical system. The compressed air needed for starter operation is taken from either an air bottle installed in the aircraft or from an external source. The flow of air to the starter is controlled by an electrical solenoid-operated air shutoff valve located in the air duct. This valve is controlled by a switch located in the cockpit. All other controls for the operation of the starter are mounted within the unit.

The starter accelerates the engine to 2300–2500 rpm (35-percent engine rpm), at which time a set of centrifugal type switches on the starter terminate the starter combustion. In the event the starter overspeeds and the centrifugal switches do not open, an emergency cutout switch on the turbine prevents the starter from exceeding 2800 rpm. The starter clutch arrangement consists of an overrunning-disengage sprag type clutch that disengages when the engine accelerates to a speed greater than that of the starter, and a slip type clutch which minimizes the initial torque shock on the drive coupling at the beginning of each starter operation.

The driving member of the clutch arrangement is geared to the starter mechanism. When engine starting rpm is reached and energy input into the starter is terminated, the starter mechanism coasts to a stop, while the member of the clutch that is connected with the engine continues to turn with the engine. The unit is equipped with a shear pin, which is designed to shear under extreme torque conditions.

We also said that some aircraft are equipped with an air bottle for starting the fuel air starter. This type of installation has an air storage bottle with a

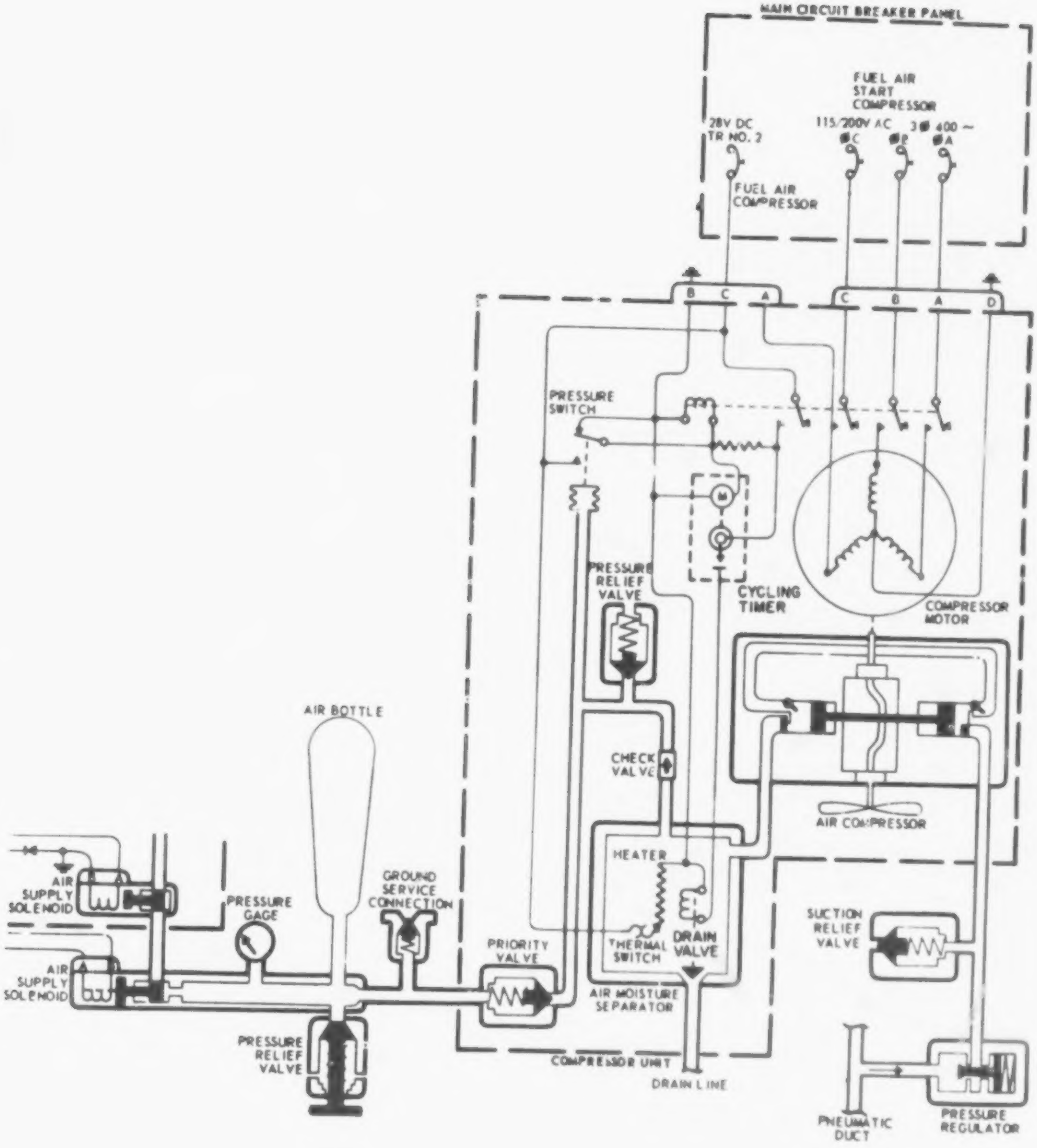

MAIN CIRCUIT BREAKER PANEL
FUEL AIR START COMPRESSOR
28V DC TR NO. 2
115/200V AC 3Ø 400 ~
ØC
ØB
ØA
FUEL AIR COMPRESSOR
B C A
C B A D
PRESSURE SWITCH
M
CYCLING TIMER
COMPRESSOR MOTOR
PRESSURE RELIEF VALVE
CHECK VALVE
AIR COMPRESSOR
AIR BOTTLE
HEATER
THERMAL SWITCH
DRAIN VALVE
AIR MOISTURE SEPARATOR
SUCTION RELIEF VALVE
AIR SUPPLY SOLENOID
PRESSURE GAGE
GROUND SERVICE CONNECTION
PRIORITY VALVE
AIR SUPPLY SOLENOID
PRESSURE RELIEF VALVE
COMPRESSOR UNIT
DRAIN LINE
PNEUMATIC DUCT
PRESSURE REGULATOR
42-1781

Figure 3-1. Air compressor circuit.

solenoid-operated control valve installed on the outlet, and an electric motor-driven air compressor to charge the storage bottle. The bottle stores enough air for two or three starts of the fuel-air starter, depending on the initial charge and the ambient temperature. The compressor automatically recharges the bottle.

The air compressor circuit, shown in figure 3-1, consists of a motor-driven air compressor; moisture separator; pressure switch; priority valve; cycling timer; heaters; check valve; and pressure-relief valve. The operation of the compressor is controlled by the pressure switch. When the air pressure in the bottle drops below 2800 ± 100 psi, the pressure switch closes and completes the circuit from the 115- to 200-volt AC bus to the compressor motor, thus energizing the three-phase compressor motor. The compressor motor will continue to operate until the pressure in the bottle reaches 3000 ± 100 psi. At this time the pressure switch opens and breaks the circuit to the motor. The air to the compressor is supplied from the aircraft pneumatic supply system through the pressure regulator. The regulator maintains the pressure at approximately 16.7 psi. The suction relief valve in the compressor supply line insures adequate air supply to the compressor if the pressure in the supply line should drop below the ambient pressure.

Now notice the cycling timer. This unit opens the drain valve in the air moisture separator every 10 to 12 minutes to keep the system free of moisture. Also included in the circuit is a thermal switch, which is set at 40° F. When the temperature in the moisture separator reaches 40° F., the thermal switch closes, completing the circuit from the 28-volt DC bus to the heater. This prevents freezing of any water that may collect in the moisture separator before the cycling timer operates.

The operation of the starter is automatically controlled by the units in the control box located on the rear of the starter. The items that are correlated through the control box, as shown in figure 3-2, are the time-delay switch, burner switch, centrifugal switches, and the control relay.

To operate the starter, the ignition and control switch must be placed in the GROUND START position and the fire switch must be in the NORMAL position. This will energize the fuel-air start power control relay. Current flow to energize the control relay is now available from ground through the control relay coil, through the closed contacts on the interlock relay, through the turbine and gear box centrifugal switches, through the burner switches, through another set of contacts on the interlock relay, through the time delay relay, and through the contacts of the fuel-air start power control relay to the 28-volt DC bus.

When the control relay closes, power is supplied to the air valve, the fuel valve, and the ignition exciter. At this time the fuel accumulator is opened by the air pressure from the starter line. Combustion then occurs, and a buildup of chamber pressure closes the low-pressure switch which removes the control of the system from the time-delay switch and also from one set of contacts of the interlock relay. After a period of approximately 1 second, the time-delay switch energizes the interlock relay. This turns off the ignition to the starter.

When the starter reaches cutout speed (2400 ± 100 rpm), the gear box centrifugal switches break the control relay holding circuit and stop the starting cycle. This type of starter is critical on the starting limitations. The limits of temperature restrict the ability of the fuel-air starter to make repeated combustion starts. Normally, two start attempts within a ½-hour period will produce a temperature approaching the maximum allowable value. If two starts are attempted within a ½-hour period, a third attempt can be made after a ½-hour cooling period provided 1650-psi air pressure is available. Successive start attempts may be made, provided a ½-hour cooling period follows each attempt. In the event you should want to cut the ½-hour waiting time, it is permissible if external cooling is used. The starter is cool enough for a start attempt if the bare hand can be held on the starter gearbox.

Exercises (422):

1. From what source does the fuel-air starter get its supply of fuel?

2. At about what percent of engine speed will the fuel-air starter turn the engine?

3. When the starter reaches its speed, what operates to stop the starter?

4. How is the fuel-air starter air bottle recharged?

5. When does the heater operate in the air moisture separator, and why does it operate?

423. Cite facts relative to the operation of pneumatic starters and analyze the operational principles.

Operation of Pneumatic Starters. Another type of starter you will no doubt have to work on is the pneumatic or pure-air starter (see fig. 3-3).

This starter is designed to provide the required torque and speed necessary to start a turbojet or turboprop engine. It is mounted on a specially designed pad. The starter output shaft is mechanically coupled to the jet engine starter drive. The starter is then driven by compressed air, ducted through a combination pressure-regulating and shutoff valves to the starter inlet. This compressed air may be supplied from ground-operated or airborne gas turbine auxiliary power units, or by air bled from the compressor of another engine in a multiengine aircraft. The compressed air is supplied to the starter through a regulating and shutoff valve which will maintain the specified inlet air pressure.

When the engine starting speed is reached, the starter must be shut off and the drive disengaged. To accomplish this automatically, two centrifugal cutout switches (fig. 3-3) are included on each starter, one driven from the starter side and one from the engine side of the clutch. The cutoff switches include a set of flyweights (not shown) driven by one clutch gear. These flyweights actuate a cutoff switch to break the circuit to the air start

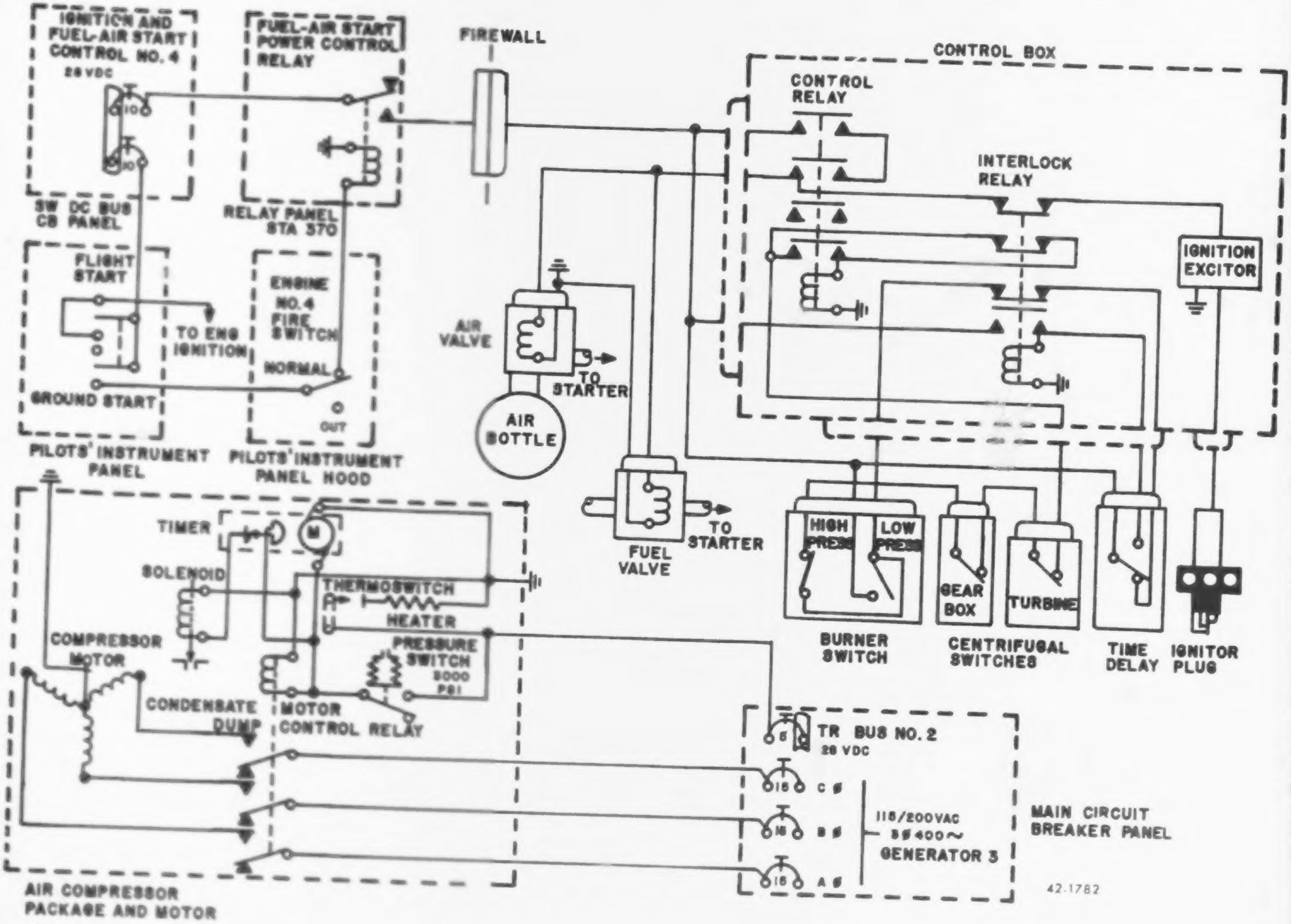

IGNITION AND FUEL-AIR START CONTROL NO. 4
28 VDC
10
10
SW DC BUS CB PANEL
FUEL-AIR START POWER CONTROL RELAY
RELAY PANEL STA 370
FIREWALL
CONTROL BOX
CONTROL RELAY
INTERLOCK RELAY
IGNITION EXCITOR
FLIGHT START
TO ENG IGNITION
GROUND START
PILOTS' INSTRUMENT PANEL
ENGINE NO.4 FIRE SWITCH
NORMAL
OUT
PILOTS' INSTRUMENT PANEL HOOD
AIR VALVE
TO STARTER
AIR BOTTLE
FUEL VALVE
TO STARTER
HIGH PRESS
LOW PRESS
BURNER SWITCH
GEAR BOX
TURBINE
CENTRIFUGAL SWITCHES
TIME DELAY
IGNITOR PLUG
TIMER
M
SOLENOID
THERMOSWITCH
HEATER
PRESSURE SWITCH 3000 PSI
COMPRESSOR MOTOR
CONDENSATE DUMP
MOTOR CONTROL RELAY
AIR COMPRESSOR PACKAGE AND MOTOR
5
TR BUS NO. 2
28 VDC
15
C ϕ
15
B ϕ
15
A ϕ
115/200VAC
3ϕ 400~
GENERATOR 3
MAIN CIRCUIT BREAKER PANEL
42-1782

Figure 3-2. Fuel-air starter control system.

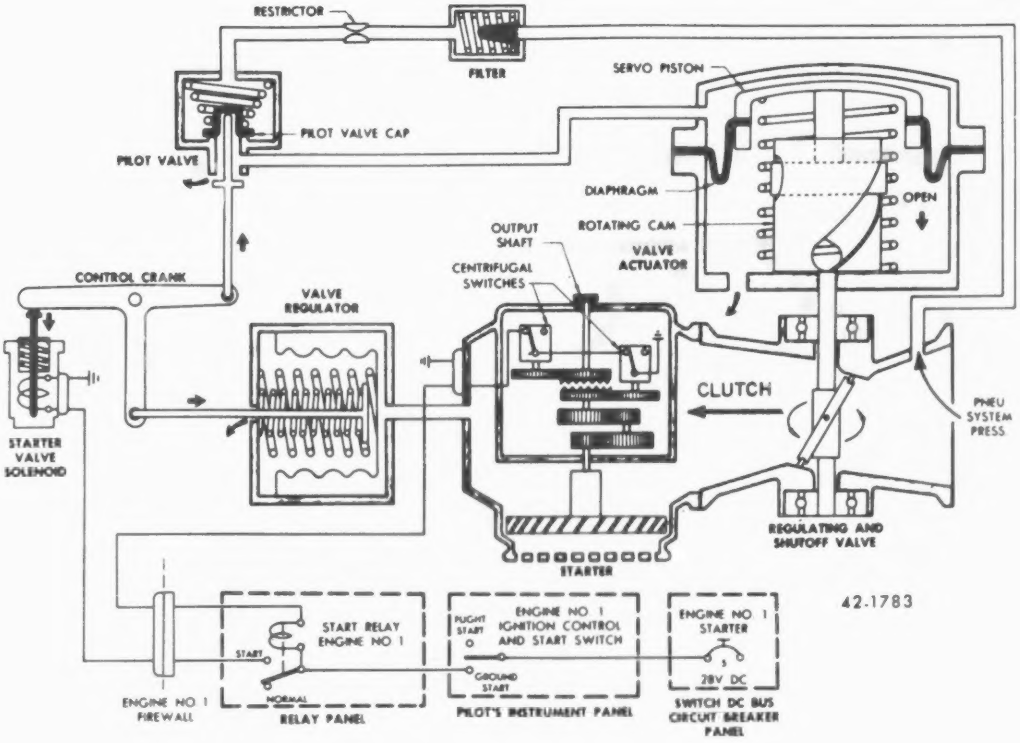

RESTRICTOR
FILTER
SERVO PISTON
PILOT VALVE CAP
PILOT VALVE
DIAPHRAGM
OPEN
OUTPUT SHAFT
ROTATING CAM
VALVE ACTUATOR
CENTRIFUGAL SWITCHES
CONTROL CRANK
VALVE REGULATOR
CLUTCH
PNEU SYSTEM PRESS
STARTER VALVE SOLENOID
REGULATING AND SHUTOFF VALVE
STARTER
42-1783
START RELAY ENGINE NO 1
START
NORMAL
FLIGHT START
ENGINE NO 1 IGNITION CONTROL AND START SWITCH
GROUND START
ENGINE NO 1 STARTER
28V DC
ENGINE NO 1 FIREWALL
RELAY PANEL
PILOT'S INSTRUMENT PANEL
SWITCH DC BUS CIRCUIT BREAKER PANEL

Figure 3-3. Pneumatic starter schematic.

solenoid when the starter shaft speed reaches 3400 rpm. This shuts off the supply of air to the starter turbine, a spring (not shown) disengages the clutch, and the turbine rotor stops rotating. The output shaft continues to run with the engine.

High-pressure air from an auxiliary air compressor, or compressor discharge air of another engine which is running, is connected to the pneumatic system pressure side of the starter. When the regulating and shutoff valve is closed, air can pass through the filter, the restrictor, and the pilot valve and be vented overboard to prevent the starter from operating.

When the ignition control and start switch (as shown in fig. 3-3) is placed to the GROUND START position, the starter valve solenoid is energized, closing the air port of the pilot valve, thus allowing air to be vented to the top side of the valve actuator. As the spring is depressed, it will open the regulating and shutoff valve. Pneumatic system pressure is then directed to the starter turbine wheel. The starter now is operating.

To keep the air pressure on the turbine wheel constant and to maintain the desired starter speed, a regulator valve is used. Notice that one end of the regulator is connected to the starter case and the other end is connected to the pilot valve by a mechanical linkage. If the pressure within the starter becomes too great, the pilot valve will allow part of the air to the actuator valve to be vented overboard. This, in turn, will close the shutoff valve and will stop the air flow to the starter.

Another controlling device, which is included in the starter, consists of the centrifugal switches mentioned previously. When the starter speed has reached its maximum limit, the centrifugal switches break the ground circuit to the start relay. At the same time, the pilot valve opens, shutting off the air flow.

The starting limitations for the pneumatic starter vary with each manufacturer; however, you should never overoperate the starter. Most starters have 1½-minute maximum operating time, followed by a 1- to 3-minute cooling period. Check the applicable technical order for limitations.

Exercises (423):

1. How many ways can air be supplied to the pneumatic starters and what are they?

2. What is the effect of an open centrifugal switch in the pneumatic starter system?

3. When high-pressure air is connected to the pressure side of the pneumatic starter and the regulating and shutoff valve is closed, where does the pressure go?

4. Energizing what component allows pneumatic system pressure to be vented to the top of the valve actuator?

5. What is the purpose of the regulator valve?

424. Point out the operating principles of the cartridge pneumatic starter and analyze the facts presented.

Operation of the Cartridge Pneumatic Starter. The cartridge pneumatic starter provides a self-contained source of power for cranking jet engines to the high speeds necessary for starting. "Self-contained" means that the starter has the ability to start the engine without the support of ground equipment. The starter is essentially a gas-driven turbine wheel coupled to the aircraft engine through a reduction gear system and an overruning clutch. The clutch disconnects the starter gear from the engine shaft, following a start, so that the engine will not drive the starter.

Energy for driving the turbine of the starter is supplied from any of three sources: expanding gases from the burning of a solid propellant charge, bleed air from an operating engine on the same aircraft, or low-pressure air from an external air source (such as an MA−1A gas turbine compressor). Thus, the cartridge pneumatic starter offers the advantages of a self-contained system and the flexibility of the conventional low-pressure pneumatic starter discussed previously. Since you are already familiar with the operating characteristics of pneumatic starters, let us discuss the operation of a cartridge pneumatic starter.

A schematic of the starter is shown in figure 3-4. When the cartridge is ignited by the cartridge squib, the burning gases released by the cartridge flow into the turbine section of the starter, as indicated by the arrows. At the same time, air is drawn through the air inlet (dotted arrows) and mixed with the cartridge gas. As the turbine wheel [illegible] accelerated, its rotary motion is transmitted through the reduction gear train and the output shaft to the engine.

Normally, when a cartridge is ignited, the energy from the cartridge is absorbed by the aircraft engine. The starter produces torque until the cartridge is spent. When the cartridge is spent, the starter coasts

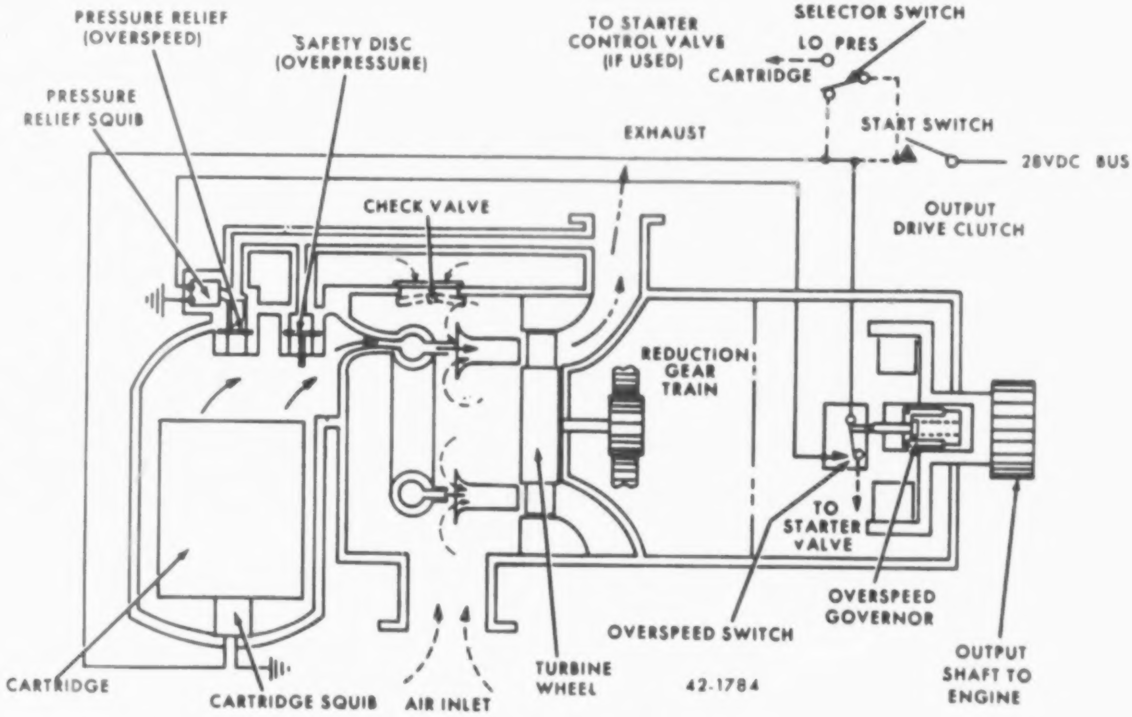

PRESSURE RELIEF (OVERSPEED)
SAFETY DISC (OVERPRESSURE)
PRESSURE RELIEF SQUIB
TO STARTER CONTROL VALVE (IF USED)
SELECTOR SWITCH
LO PRES
CARTRIDGE
EXHAUST
START SWITCH
28VDC BUS
CHECK VALVE
OUTPUT DRIVE CLUTCH
REDUCTION GEAR TRAIN
TO STARTER VALVE
OVERSPEED GOVERNOR
OVERSPEED SWITCH
OUTPUT SHAFT TO ENGINE
CARTRIDGE
CARTRIDGE SQUIB
AIR INLET
TURBINE WHEEL
42-1784

Figure 3-4. Cartridge pneumatic starter schematic.

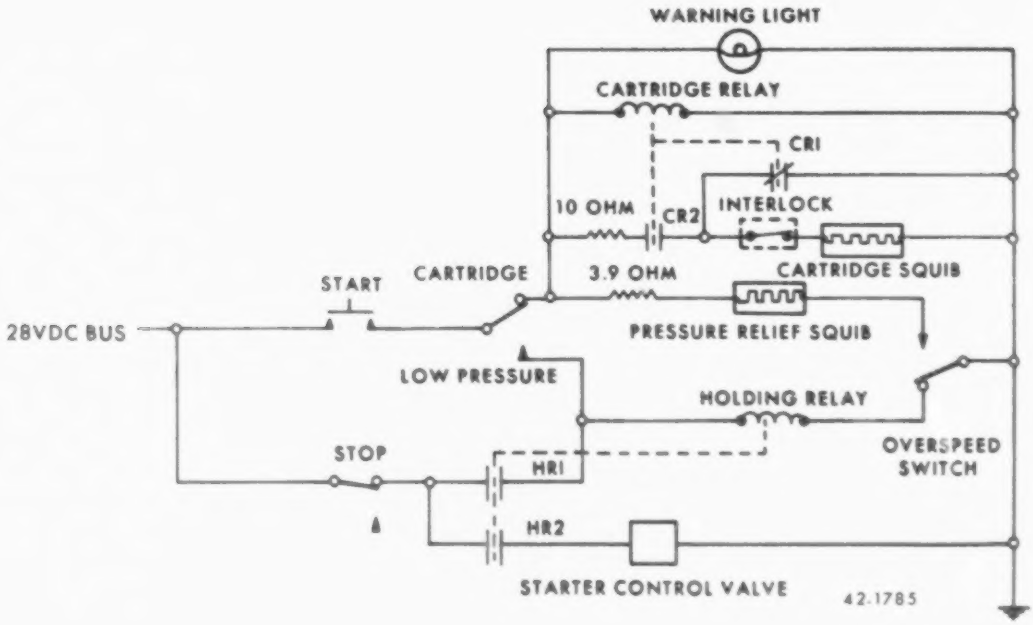


Figure 3-5. Cartridge pneumatic starter electrical system.

to a stop and the engine, now at greater than self-sustaining speed, continues to accelerate to idle rpm. It should be noted that once the cartridge is ignited, it will continue to burn, and there is no way to terminate the cycle. It is obvious, then, that various protective devices are necessary to protect the system from overspeed or overpressure conditions.

The safety disc, shown in figure 3-4, is located between the cartridge assembly and the exhaust of the starter and provides protection against overpressure conditions. Although the breech of the starter (the part that holds the cartridge) is capable of withstanding 3000-psig pressure, the safety disc is designed to rupture between 1600 and 2000 psig. When the safety disc ruptures, the cartridge gas is vented into the exhaust. Some of the gas is still applied to the turbine wheel, but the turbine wheel now produces less power and the engine may not start.

The pressure-relief valve, also shown in figure 3-4, provides protection during overspeed conditions of the starter. Overspeed of the starter is most commonly caused by a sheared shaft, but it may also be caused by a faulty cartridge that burns too rapidly. If the starter goes into an overspeed condition during the starting cycle (start switch ON), the overspeed switch contacts of the overspeed governor close and complete a circuit to the pressure relief squib. When voltage is applied to the pressure-relief squib, the squib fires and ruptures the pressure-relief valve. This vents the cartridge gas to the exhaust of the starter and reduces the speed of the turbine wheel.

CAUTION: The pressure-relief squib must always be handled with extreme care. Wear safety glasses and gloves when handling the squib. Except when it is connected into the circuit, the leads of the squib will be shorted together to prevent inadvertent firing. The squib can be fired with approximately 0.5 ampere of current, and even a weak flashlight battery may contain enough power to fire the squib. If it is necessary for you to perform a continuity or resistance check of the squib circuit, be sure to use an ohmmeter with no more than 0.5 ampere output. A standard multimeter will fire the squib.

A schematic of the electrical system used with the cartridge pneumatic starter is shown in figure 3-5. When the start switch is moved to the start position, voltage is applied to the cartridge relay. When the cartridge relay energizes, the normally closed contacts CR1 open and the normally open contacts CR2 close. This completes a circuit through the 10-ohm resistor and the interlock switch (mounted in the breech assembly) to the cartridge squib. At the same time, the warning light comes on. Note in figure 3-5 that the selector switch must be in the CARTRIDGE position to fire the cartridge squib. If the overspeed contacts should close, a ground is completed for the pressure-relief squib and the squib will fire if the start switch is ON and the selector switch is in the CARTRIDGE position.

When operating the starter for a cartridge start, it is very important that you be familiar with the operation of the starter. For example, the overspeed contacts close when the engine reaches a certain speed during the normal starting cycle. If the starter switch is closed at that time and the selector switch is in the CARTRIDGE position, the pressure-relief squib will ignite even though the turbine wheel is not in an overspeed condition.

Exercises (424):

1. What is the safety disc used for in the cartridge pneumatic starter?

2. What is the purpose of the pressure-relief valve?

3. What are the most common causes of overspeed conditions?

4. Explain what the pressure relief squib does.

5. What precautions should be taken when handling the pressure relief squib?

6. Will the pressure-relief squib be ignited during a low-pressure start?

425. Name the main parts and state the approximate voltage output of the AC ignition system, and name the main parts and state the function of the vibrator unit in a typical DC ignition system.

Alternating-Current Ignition System. One of the simplest ignition systems for gas turbine engines uses 115-volt, 400-hertz AC as a power supply and, by means of high-ratio transformers, steps the voltage up to approximately 20,000 volts. This system is schematically shown in figure 3-6. An inverter supplies the 115-volt, 400-hertz power to the AC bus and ignition relay. When the ignition switch is closed, the ignition relay is energized by direct current from the DC power supply. This action closes the AC circuit to the ignition transformer. The transformer develops the high-voltage (20,000-volt) alternating current that is delivered to the igniter plugs.

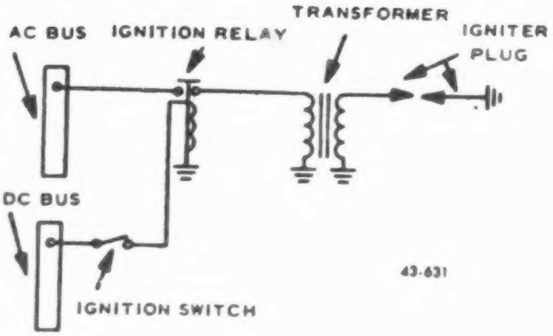


Figure 3-6. Simple alternating-current ignition circuit.

Direct-Current Ignition System. A simple DC ignition system consists of a vibrator, a transformer, and igniter plugs. A system of this type is shown in figure 3-7. The vibrator unit that you see in the figure changes the 28 volts of direct current into a pulsating current so that the voltage may be stepped up through the transformer. The high voltage induced in the transformer secondary winding is then applied to the igniter plug.

Exercises (425):

1. What are the main parts of an alternating-current ignition system?

2. What are the main parts of a direct-current ignition system?

3. Approximately how many volts does the AC ignition develop at the igniter plug?

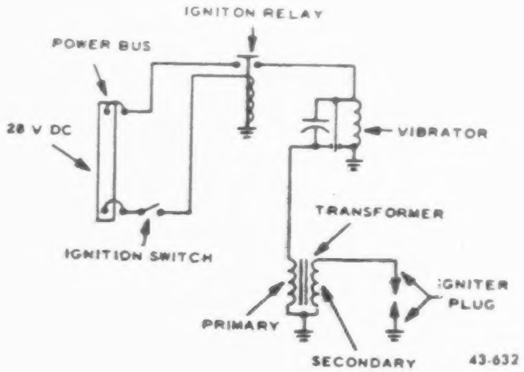


Figure 3-7. Simple direct-current ignition circuit.

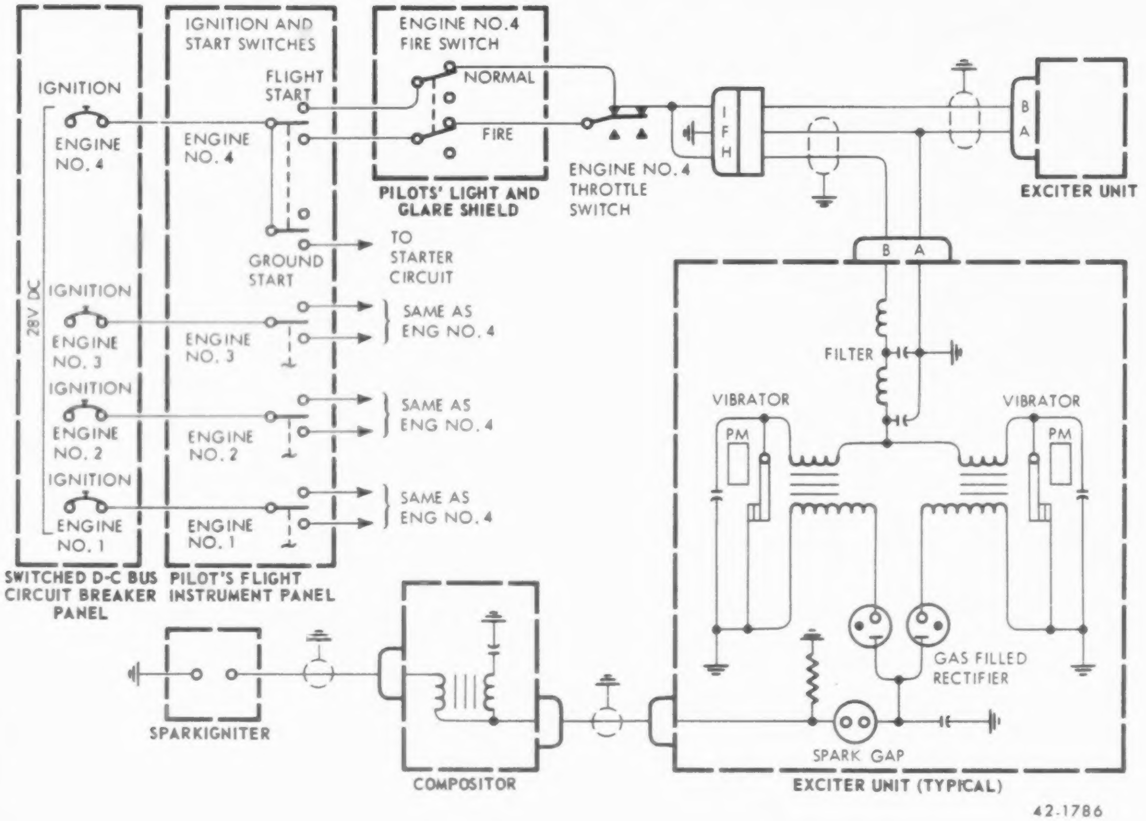

IGNITION
ENGINE NO. 4
IGNITION AND START SWITCHES
FLIGHT START
ENGINE NO. 4
GROUND START
TO STARTER CIRCUIT
ENGINE NO.4 FIRE SWITCH
NORMAL
FIRE
PILOTS' LIGHT AND GLARE SHIELD
ENGINE NO. 4 THROTTLE SWITCH
I F H
B A
EXCITER UNIT
28V DC
IGNITION
ENGINE NO. 3
ENGINE NO. 3
SAME AS ENG NO. 4
IGNITION
ENGINE NO. 2
ENGINE NO. 2
SAME AS ENG NO. 4
IGNITION
ENGINE NO. 1
ENGINE NO. 1
SAME AS ENG NO. 4
SWITCHED D-C BUS CIRCUIT BREAKER PANEL
PILOT'S FLIGHT INSTRUMENT PANEL
FILTER
VIBRATOR
VIBRATOR
PM
PM
GAS FILLED RECTIFIER
SPARK GAP
SPARKIGNITER
COMPOSITOR
EXCITER UNIT (TYPICAL)
42-1786

Figure 3-8. Engine ignition circuit (C–135A).

4. What function does the vibrator unit in the DC ignition system perform?

426. Give the purpose of the C–135 engine ignition circuit, and point out the differences between the "A" and "B" model circuits.

Purpose of the Circuit. The engine ignition circuit is used to ignite the fuel and air mixture in the engine while starting the engine and can be used for limited periods to ensure continuous combustion in flight. The circuit supplies about two high energy sparks per second that are capable of vaporizing large amounts of fuel and blasting away carbon deposits from around the center electrode of the spark igniter.

The circuit contains an exciter, a compositor, spark igniter, and the control switches necessary to operate the system.

The "A" Model Circuit. The ignition circuit on "A" model airplanes has an ignition control and start switch, a throttle switch, two exciters, two compositors, and two spark igniters for each engine (see fig. 3-8). The engine fire switch is in the circuit for each engine and will open the ignition circuit if it is pulled. With the ignition control and start switch in the GROUND START position, power is applied to the exciters through the fire switch and the throttle ignition switch. The throttle range switch is closed when the throttle lever is advanced between 2° and 28.5° from engine cutoff. With the ignition control and start switch in the FLIGHT START position and the throttle range switch bypassed, the position of the throttle will have no effect on ignition circuit operation. The exciters convert the DC power to high voltage pulses by means of two vibrators, transformers, and rectifier tubes. The pulses charge the exciter units storage capacitor until the charge is large enough to arc across the spark gap. This arc causes the primary of the compositor to induce a high voltage in the secondary, which will cause an arc to occur at the spark igniter. The compositor storage capacitor will discharge when the voltage arcs across the gap of the igniter, creating a very high energy spark.

The "B" Model Circuit. The ignition circuit on "B" model airplanes consists of an ignition control and start switch, a start lever ignition switch, two ignition units, and two spark igniters for each engine (see fig. 3-9). The engine fire switch will remove power from the ignition circuit if it is pulled. The ignition control and start switch applies power directly to the ignition unit when it is in the FLIGHT START position and through the start lever ignition switch to the ignition unit when it is in the GROUND START position. The start lever ignition switch is closed when the start lever is advanced from 6° to 35° from cutoff. When power is applied to the ignition units, the DC power is converted to pulses, stepped up in voltage, and stored in a storage capacitor. Successive pulses will build the charge on the storage capacitor until the charge is large enough to arc across the spark gap. The compositor steps up the voltage causing an arc to form at the spark-igniter electrodes. This discharges the capacitor in the primary of the compositor, creating a high energy spark.

Exercises (426):

1. What is the purpose of the C – 135 ignition circuit?

2. How many high energy sparks are produced by the circuit each second?

3. What can the high energy sparks do other than vaporizing fuel?

4. Use figures 3-8 and 3-9, and point out one of the differences in the "A" and "B" model after the signal leaves the fire switch.

5. Point out the difference between compositors in the "A" and "B" model.

427. Give precautions that you must follow during ignition system maintenance, to include system checkout.

Maintenance of the Ignition System. Several precautions must be observed whenever you are performing maintenance on the ignition system. You should never work on this system unless the ignition and start switch is placed in the OFF position and all necessary circuit breakers are pulled. Also, do not supply input voltage to the ignition unit unless an igniter plug is connected to the unit with an ignition lead.

You must remember that voltages in the ignition units are dangerously high and could result in serious injury if caution is not used when working on this system. It is necessary, therefore, to discharge the unit by grounding the connector spring of the igniter plug lead. To discharge a capacitor when the ignition lead is connected to an igniter plug that is removed from the engine, use a screwdriver, as shown in figure 3-10, to ground the center electrode to the lower shell. Be sure that the screwdriver is in contact with the lower shell before touching the electrode. Exercise extreme care in this operation, as current from a charged capacitor can cause injury.

Checkout Procedures. The checkout procedure for the jet engine ignition system requires that the aircraft be parked in an area that is free from fuel fumes. You must connect external power to the aircraft and pull the applicable engine-starter circuit breakers. Next, advance the throttle to the START position and hold the applicable ignition control and start switch in the GROUND START position. An assistant should be stationed near the engine so that he can make sure that he can hear the discharge of both igniters. If the "ear check" proves satisfactory, disconnect the electrical power and push in the starter circuit breaker. If the spark at the igniter plug sounds weak, or if you cannot tell that both igniters are firing properly, get some assistance from the engine shop.

Wearing rings while working on the ignition system will result in severe electrical shock and burns if the wearer should accidentally come in contact with live electrical circuits. In view of the seriousness of this hazard, you must refrain from wearing finger rings while engaged in aircraft and engine operations and maintenance.

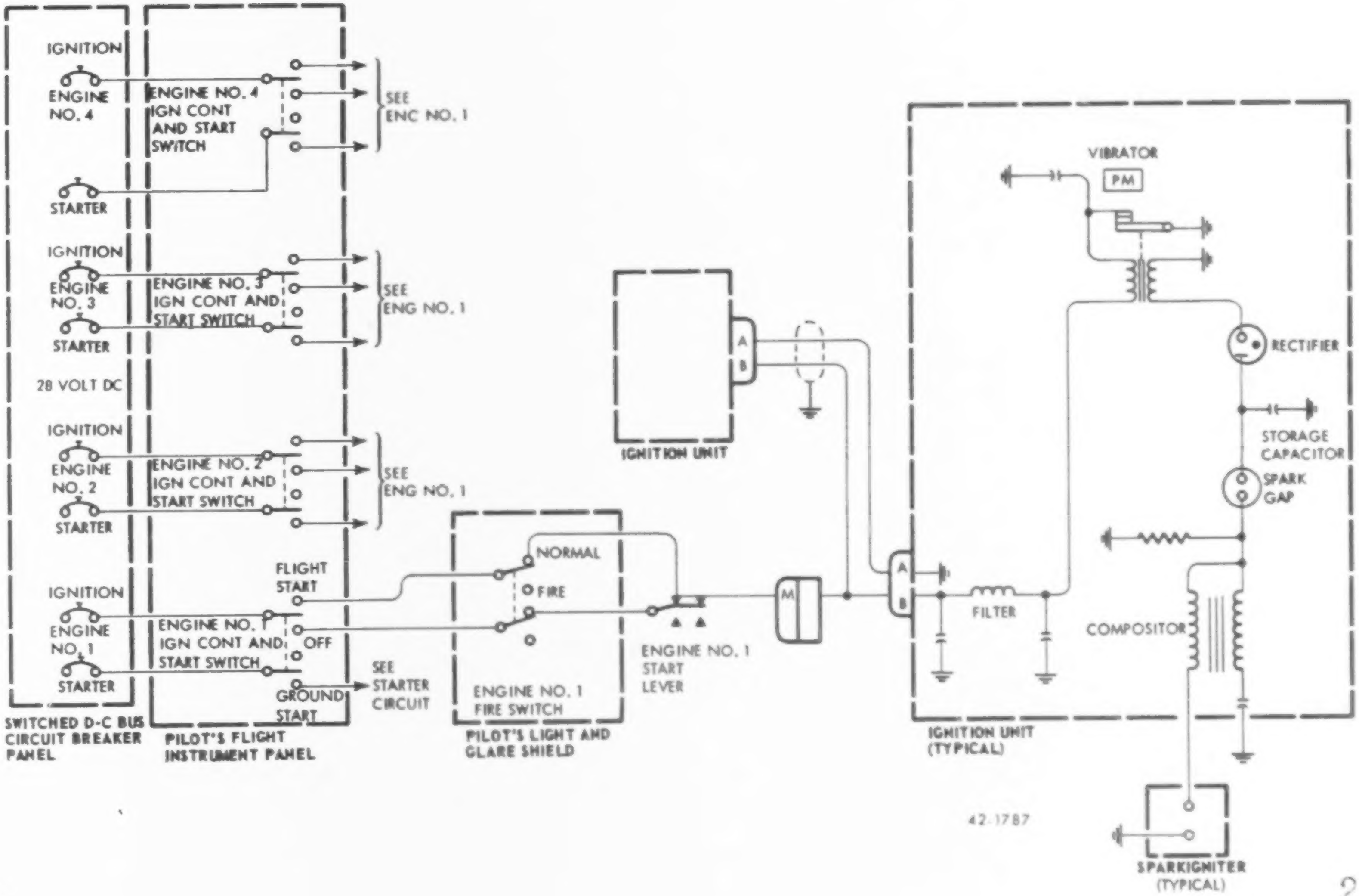
Exercises (427):

1. Give precautions that you must follow when working on the ignition system.

2. Where should the airplane be parked when the ignition system is being checked out?

3. What's the next step to take after the throttle has been advanced to the START position?

284



IGNITION
ENGINE NO. 4
ENGINE NO. 4 IGN CONT AND START SWITCH
SEE ENC NO. 1
STARTER
IGNITION
ENGINE NO. 3
ENGINE NO. 3 IGN CONT AND START SWITCH
SEE ENG NO. 1
STARTER
28 VOLT DC
IGNITION
ENGINE NO. 2
ENGINE NO. 2 IGN CONT AND START SWITCH
SEE ENG NO. 1
STARTER
FLIGHT START
IGNITION
ENGINE NO. 1
ENGINE NO. 1 IGN CONT AND START SWITCH
OFF
STARTER
GROUND START
SEE STARTER CIRCUIT
SWITCHED D-C BUS CIRCUIT BREAKER PANEL
PILOT'S FLIGHT INSTRUMENT PANEL
NORMAL
FIRE
ENGINE NO. 1 FIRE SWITCH
PILOT'S LIGHT AND GLARE SHIELD
ENGINE NO. 1 START LEVER
A
B
IGNITION UNIT
M
A
B
FILTER
VIBRATOR
PM
RECTIFIER
STORAGE CAPACITOR
SPARK GAP
COMPOSITOR
IGNITION UNIT (TYPICAL)
42-1787
SPARKIGNITER (TYPICAL)

Figure 3-9. Engine ignition circuit (C-135B).

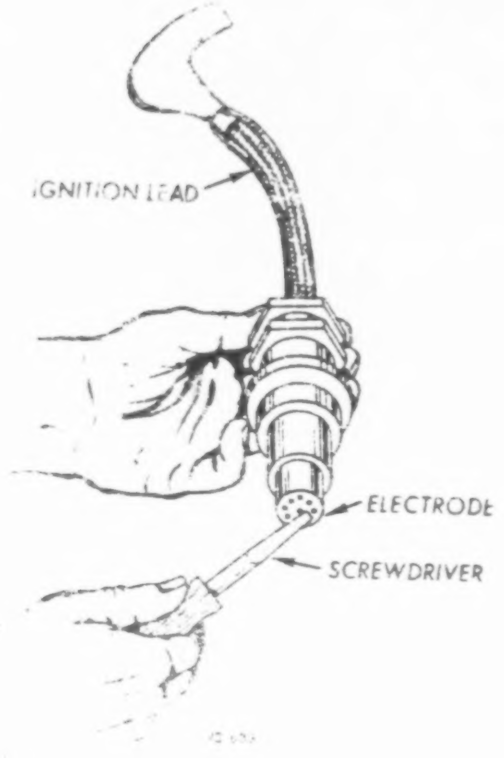


Figure 3-10. Grounding an igniter unit condenser.

4. What should you do if one of the spark igniters sounds weak during checkout?

5. Why should you refrain from wearing rings while working on the ignition system?

428. Cite reasons for inspecting and troubleshooting the power plant system.

Inspecting the Power Plant Electrical System. Inspections are necessary to correct malfunctions before they occur. While you are inspecting the aircraft, you might spot a component that has a loose nut. If this condition were allowed to remain, the nut could fall off and possibly short out a circuit or damage the engine, should it get into the intake. Loose nuts are not the only thing you look for. Components and connector plugs should be secure and safety-wired when called for.

When you perform a phased inspection, you will be provided with inspection workcards. These cards contain all the items that are required to be inspected during that particular inspection. As long as you follow the instructions on them, you should not have any problems performing the inspection and the power plant electrical system should operate with fewer defects.

When performing inspections, don't limit yourself to only those items on the workcards. Be observant of any problems in the area you are inspecting.

Troubleshooting the Power Plant Electrical System. Troubleshooting is a systematic approach that you will use in locating a malfunction in an aircraft system. There are as many ways to troubleshoot as there are people. In other words, everyone develops his own ways to troubleshoot. However, one has to start somewhere. If you follow the troubleshooting charts in appropriate technical orders, you will never go wrong.

Let's take a typical problem in the power plant system. The pilot wrote the discrepancy down, and it said that he could not get ignition even though the starter turned the engine.

By analyzing the writeup, you can eliminate half of the work. You know that the starter system is operating, so this means that all the various centrifugal switches and relays in that system are operating properly. The main problem is in the ignition circuitry. Since the igniter is the last item in the system, this then would be a good place to start troubleshooting. You will need an assist from the engine shop if you suspect a defective igniter plug. After they have checked the plug and replaced it, if necessary, an operational check of the entire starter/ignition must be performed to insure that the malfunction has been corrected.

If the engine people determined that the plug was serviceable, our next check would be aircraft wiring. We make this check to determine if the wiring between the transformer and the igniter plug is good or not. We should make this check with an ohmmeter or megger.

Based on what we just discussed, what then would be the defect if there was no spark at the igniter plug, the wiring checks all right, and there is normal power to the input of the transformer? Logical troubleshooting would tell you that the transformer is defective. After the defective transformer is removed and a serviceable one placed in the system, an operational check of the entire system must be performed. This holds true regardless of whether you found a broken wire, a circuit breaker that someone forgot to push in, or a major component was replaced. The operational check cannot be overstressed, as the troubleshooting cycle is not complete until the repair has been checked.

Exercises (428):

1. What is the main reason for inspecting a system?

2. What guide lines do you utilize when performing an inspection?

3. State the first step in troubleshooting.

4. What is the final step in troubleshooting?

429. Identify procedures used when installing, repairing, modifying, overhauling, and bench checking components.

Maintaining the Power Plant Electrical System. In order to properly maintain the electrical portion of the power plant system, you must know more than just system operation. How to properly install, repair, modify, overhaul, and bench check components is just another part of your job. Let's take a brief look at each of these important functions.

Installing components. Anytime a component is installed on an aircraft, care must be taken to make sure that the component is suitable for that particular installation. If the prime item cannot be obtained through regular supply channels, an authorized substitute may be utilized; however, the substitute part must have the same specifications as the prime item. The applicable TO for the system component you are installing must be utilized in order to obtain any special warnings or instructions relative to that system. The TO will also list any pertinent data such as torque values and adjustments to be made.

Repairing components. After an electrical component in the power plant system has been determined to be defective, an operational unit is then installed. Repair of the electrical components is extremely limited since the majority of them are sealed units. These units are turned in to supply and repaired at a depot-level facilily.

Modifying and overhauling components. Should a component continue to fail, and upon close examination you find that the same item in that component is the cause of failure, a change will most likely result. This change is called a modification and may be completed during an overhaul or a phased inspection. Also, depending on the urgency, the aircraft may be immediately grounded until the modification is complete. This depends solely on the urgency of the modification.

A modification must be approved by AFSC (Air Force Systems Command) and is in the form of a TCTO (time compliance technical order). The TCTO tells you when, where, and how the modification is to be completed. Any parts needed to complete the modification are included in the TCTO kit. Normally, you do not overhaul power plant electrical components as overhaul of these components is usually done at depot-level maintenance.

Bench checking components. The electrical components in the power plant systems discussed are of the "remove and replace" type. Since there is basically no repair to be done to them at field-level maintenance, other than doing small tasks such as straightening pins on connector plugs, depot performs the bench checks after repairing these components. In some of the larger shops, locally manufactured testers have been built by shop personnel to bench check these components. If you are lucky enough to be assigned to one of these shops, make use of the test equipment and you will find your job a lot easier.

Exercises (429):

1. Where would you find torque values for a specific installation?

2. What repairs are made on sealed components?

3. What is the authority for modifications and who approves them?

3-2. Fuel Control Systems

The fuel system is one of the major aircraft systems. The operation of the aircraft depends largely upon an uninterrupted fuel supply. The number of electrical components used in a fuel system necessitates a very thorough understanding of system operation as well as component function by the electrical systems specialist.

The information presented in this section provides you with the basic knowledge you will need to maintain, troubleshoot, and repair the fuel system control circuits and the control system components. A multiengine fuel system (B−52) has been selected for this discussion, because this system contains many components that will be found in other types of Air Force aircraft.

430. Analyze components of the fuel control system and cite operational characteristics of these components.

Fuel System Components. Control of the fuel system is accomplished through the use of various switches and indicators located on the fuel management panel and the auxiliary panel, shown in figure 3-11. In the discussion to follow, all reference to component operation will be to numbered switches on these two panels.

Boost pumps. In our discussion, we will cover the boost pumps and auxiliary boost pumps located in the fuel tanks. Both main tank boost pumps and auxiliary tank pumps are controlled by switches located on the fuel management panel (fig. 3-11). Four guarded toggle switches, marked MAINS 1, 2, 3 and 4, control main tank boost pumps. By placing a main tank boost pump switch in the ON position, all pumps in that tank will start simultaneously and supply fuel to an engine.

The auxiliary fuel pumps are controlled by flow control switches on the fuel management panel. The fuel flow control switches are of the rotary type and control both the feed valves and the auxiliary pumps associated with the selected tank.

These boost pumps are driven by 115/200-volt, 400-Hz, three-phase AC induction motors. The boost pumps are not repaired at the local level. They must be returned to the depot for overhaul where the proper test equipment is available.

Fuel valves. There are several types of valves used in a fuel system, but for the purpose of this discussion, we will only talk about three of them: motor-driven sliding gate, motor-driven plug, and float-type control valves.

The fire shutoff valves are motor-driven sliding-gate-type valves. Each valve is provided with an indicator, located on the valve, to provide a visual means of checking the valve position during operational checks or when performing system maintenance. The valves are individually controlled by a microswitch actuated by throttle linkage and by the fire shutoff switch.

The crossfeed valves are motor-driven rotary-plug-type shutoff valves. These valves are powered by DC from the aircraft bus through the flow control switches. The flow control switches are located on the fuel management panel. A crossfeed valve is also provided with an indicator located on the actuator. The switches for the crossfeed valves are numbered 9, 10, 11 and 12 on the fuel management panel.

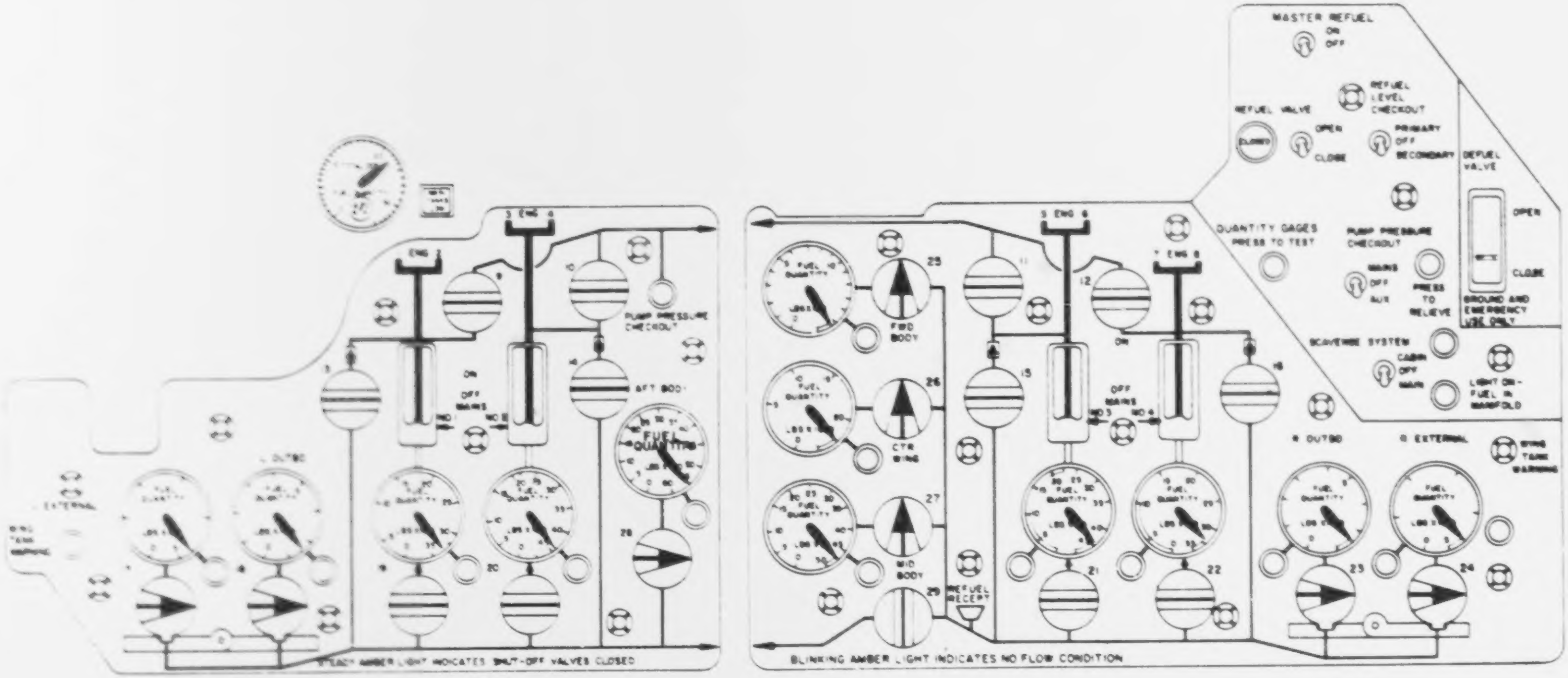
The auxiliary tank engine feed control valves are rotary-plug-type valves and are numbered 13, 14, 15 and 16 on the fuel management panel.

The system is also provided with two motor-driven sliding-gate-type interconnect valves. These valves allow the left wing and aft body tanks to be connected to the right wing, midbody and the forward body tanks. The interconnect valves are controlled by switch number 29 on the fuel management panel. These valves are open during refueling, defueling, and fuel transfer operations.

A main refuel vaive, located in the refuel manifold downstream from the air refueling and single-point refueling receptacles, isolates the refuel manifold from the main fuel manifold. The refuel valve is an electrically operated sliding-gate-type valve and is controlled by the refuel valve switch on the auxiliary refuel system panel. For emergency operation, the valve may be controlled through a cable system by a refuel valve emergency control lever. The valve incorporates both open and close limit switches to control valve movement and operates a C1-type indicator located on the refuel system panel.

The defuel valve is a motor-driven gate-type valve controlled by the defuel switch on the auxiliary refuel system panel. The defuel valve switch is covered by a guard when it is in the CLOSED position and is also marked GROUND AND EMERGENCY USE ONLY. The defuel valve is used to defuel the fuel tanks through the single point refueling receptacle.

Fuel level control valve. Each fuel tank is provided with one dual fuel level control valve, except the Nos. 1 and 4 tanks, the outboard wing tanks, and the aft body tank, which are provided with two. The purpose of each valve is to admit fuel into each tank during fuel servicing and to shut off fuel flow automatically when the tank is full, either by weight or volume. Fuel can also be shut off at any level less than full when the fuel flow control switches are moved to a CLOSED position or the master refuel switch to OFF position. The valves are normally held closed by spring action against the primary diaphragm (fig. 3-12). To open the valve with fuel pressure in the main manifold and the valve in the CLOSED position, all three solenoids must be energized and all three pilot valves must be opened. Failure of either poppet value or any one pilot valve to open should prevent the valve from opening. Moving the fuel flow control switch for the affected valve to REFUEL position should cause the primary and secondary poppet valves and the lockout pilot valves to open. When fuel trapped in both float chambers is drained, gravity acting on each float could cause the primary and secondary pilot valves to open. Finally, when the three pilot valves and two poppet valves are all open, the incoming fuel pressure lifts the primary diaphragm and holds the valve open. The valve may then remain open until both floats are actuated by the rising level of fuel in the tank. Both floats should act to close their respective pilot valves whenever the tank fuel level rises to within 2.10 (±0.25) inches of the fuel level control valve mounting pad. Both floats are actuated at the same level. Hence, the valve is dual-float but not dual-level actuated. When the fuel level control valves are closed by float actuation, the tank is full by volume; however, such a condition may never occur, depending upon the temperature and density of fuel being loaded. All fuel level control valves are connected in series with a switch located in the fuel quantity indicator for that tank between the valves and electrical power source. When the fuel quantity indicator pointer for any tank reaches the red line, the switch opens, causing the affected tank valves to close.


MASTER REFUEL
ON
OFF
REFUEL LEVEL CHECKOUT
REFUEL VALVE
CLOSED
OPEN
CLOSE
PRIMARY
OFF
SECONDARY
DEFUEL VALVE
OPEN
CLOSE
GROUND AND EMERGENCY USE ONLY
QUANTITY GAGES PRESS TO TEST
PUMP PRESSURE CHECKOUT
MAINS
OFF
AUX
PRESS TO RELIEVE
SCAVENGE SYSTEM
CABIN
OFF
MAIN
LIGHT ON- FUEL IN MANIFOLD
R OUTBD
R EXTERNAL
WING TANK WARNING
L EXTERNAL
L OUTBD
WING TANK WARNING
ENG 2
3 ENG 4
5 ENG 6
7 ENG 8
PUMP PRESSURE CHECKOUT
AFT BODY
ON
OFF
MAINS
NO 1
NO 2
NO 3
NO 4
FUEL QUANTITY
FWD BODY
CTR WING
MID BODY
REFUEL RECEPT
25
26
27
28
29
21
22
23
24
STEADY AMBER LIGHT INDICATES SHUT-OFF VALVES CLOSED
BLINKING AMBER LIGHT INDICATES NO FLOW CONDITION

42-1788

Figure 3-11. Typical fuel management panel.

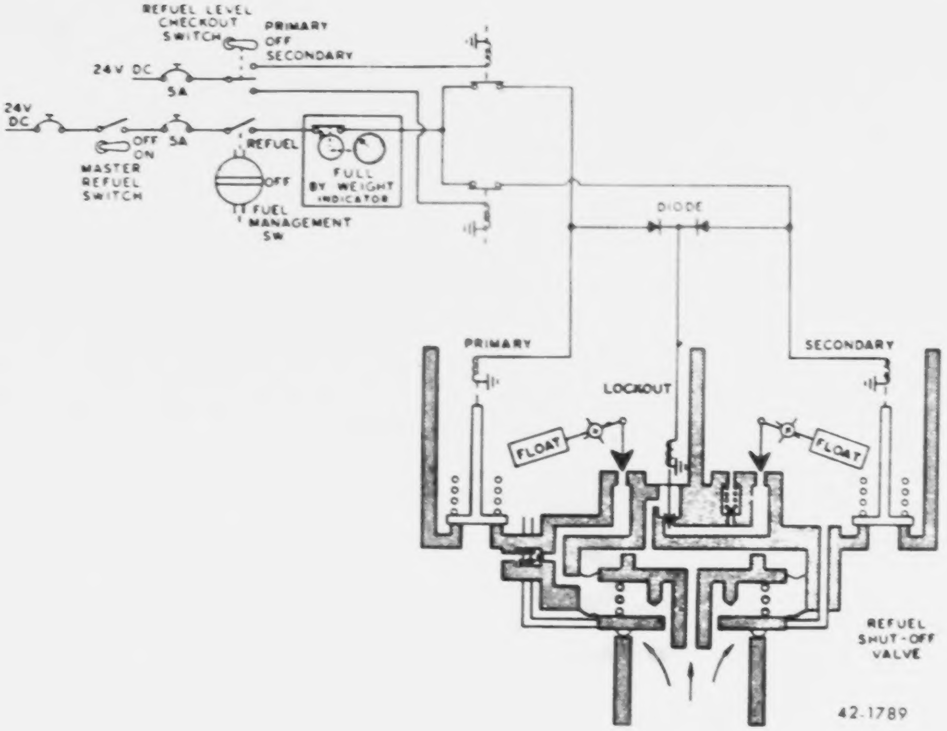


Figure 3-12. Fuel level control.

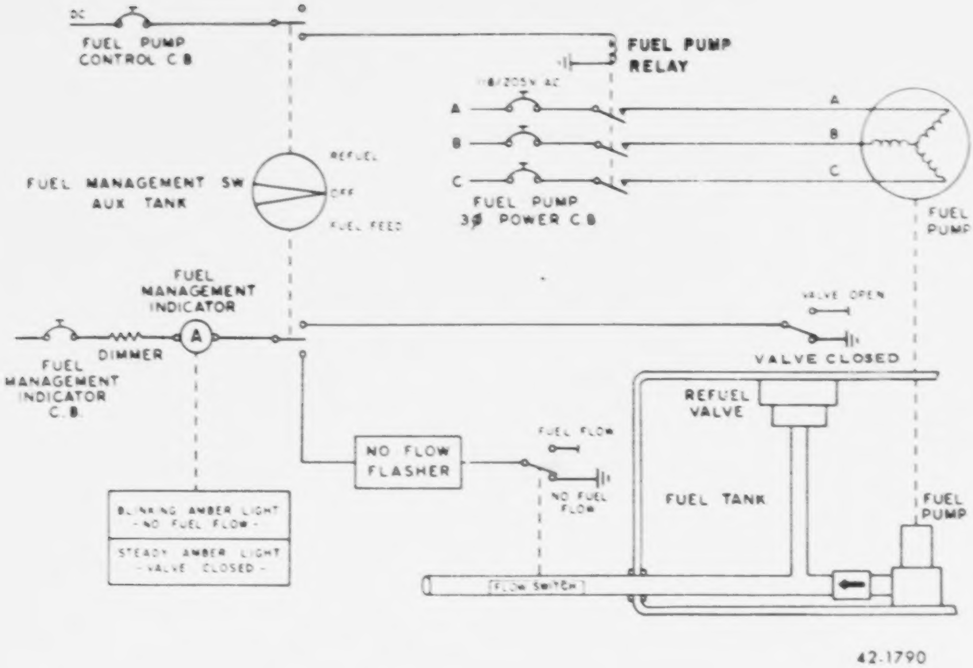
Fuel flow indicating system. A fuel flow indicating system (see fig. 3-13) provides an indication of no fuel flow for each auxiliary fuel tank by flashing the associated amber fuel flow indicator light on the fuel system panel. The system consists of a fuel flow indicator switch and an amber indicator light for each auxiliary tank and an eight-channel electronic flasher. The indicating system is energized by placing the corresponding auxiliary tank fuel flow control switch to the FUEL FEED position.

The fuel flow indicator switch is line mounted in the fuel manifold for each auxiliary tank. Since the manifolds are routed through the fuel tanks or cells, the switches operate submerged in fuel. The flow indicator switch incorporates a swing flapper which permits fuel flow in both directions for fuel feeding or refueling. When fuel flow causes the flapper to be moved in the direction of pump discharge flow, a normally closed microswitch is opened. When the flapper is in the vertical no-flow position or when it is moved in the direction of refuel flow, the microswitch remains closed. This provides a ground circuit for the associated channel of the no fuel flow flasher unit. As the boost pump discharge flow increases, the swing flapper should cause the microswitch to open at a flow rate above 800 pounds per hour and close at a flow rate below 800 pounds per hour.

An eight-channel electronically controlled no fuel flow flasher indicates fuel flow conditions in the auxiliary fuel system. When a no-flow or reverse-flow condition exists, the no-flow indicator switch provides a ground circuit to a channel of the electronic flasher. As a result, the flasher provides an intermittent ground for the amber fuel flow indicator light on the fuel system panel adjacent to each auxiliary tank fuel quantity indicator. If a channel of the flasher is energized by placing the corresponding auxiliary tank fuel flow control switch to FUEL FEED position, the intermittent ground provided by the flasher will cause the indicator light to cycle ON and OFF at a rate of 40 to 100 times per minute. When normal fuel flow is resumed, the fuel flow indicator switch removes the ground signal from the flasher channel, and the channel returns to the monitoring condition.

A dual-purpose fuel flow indicator amber light for each auxiliary tank is located on the fuel system panel adjacent to the associated fuel quantity indicator. The light flashes to indicate a no fuel flow condition during fuel feeding and glows steadily to indicate closed fuel level control valves during refueling. Brightness of the indicator light is controlled by dimmer control unit No. 2. The auxiliary tank fuel flow control switch energizes the no-flow indicating circuit when placed in the FUEL FEED position, and activates the fuel level control valve closed indicating circuit when placed in the REFUEL position.

Boost pump pressure checkout system. The boost pump pressure checkout system provides a means of



DC
FUEL PUMP CONTROL C.B
FUEL PUMP RELAY
118/205V AC
A
B
C
FUEL PUMP 3∅ POWER C.B
A
B
C
FUEL PUMP
FUEL MANAGEMENT SW AUX TANK
REFUEL
OFF
FUEL FEED
FUEL MANAGEMENT INDICATOR
A
DIMMER
FUEL MANAGEMENT INDICATOR C.B.
VALVE OPEN
VALVE CLOSED
REFUEL VALVE
NO FLOW FLASHER
FUEL FLOW
NO FUEL FLOW
FUEL TANK
FUEL PUMP
BLINKING AMBER LIGHT - NO FUEL FLOW -
STEADY AMBER LIGHT - VALVE CLOSED -
FLOW SWITCH
42-1790

Figure 3-13. Fuel flow indicating system.

ground checking individual boost pumps in both the main and auxiliary tanks. This verifies that the pump discharge pressure at no-flow is within the permissible range. The system consists of a green indicator light, a control switch, a press-to-relieve switch on the fuel system panel, a pump checkout pressure switch, a solenoid valve, and a check valve. The electrical schematic for the system is shown in figure 3-14. Since the pump pressure checkout switch samples pressure from the engine fuel crossfeed manifold, pressure from the boost pump to be checked must be routed to the crossfeed manifold by opening the required control valves. Individual boost pumps are checked by pulling and resetting the boost pump control circuit breakers.

A dual-pressure switch contains two independent switches which are actuated at different fuel pressures by a single diaphragm. The switch for the main tank boost pump is set to close the circuit to the green pressure checkout indicator light on the fuel system panel at 10 (±1) psi fuel pressure and to open when the pressure drops to 6 psi. The switch for the auxiliary tank boost pumps closes at 24 (±1) psi and opens at a minimum pressure of 19 psi.

A three-position toggle switch on the fuel system panel may be positioned to select and energize the desired microswitch in the dual pressure switch. The switch has MAIN, OFF, and AUXILIARY positions. In the MAIN position, the indicator light is controlled by the low pressure (10 (± 1) psi) switch and is used while checking the discharge pressure of the main tank boost pumps. In the AUXILIARY position, the high-pressure (24 (±1) psi) switch is used to check the discharge pressure of the auxiliary tank boost pumps. When the switch is in the OFF position, the checkout system is deenergized.

A solenoid-type drain valve is used to relieve the pressure in the crossfeed manifold after the checkout of each pump (see fig. 3-14). The 24-volt DC solenoid valve is controlled by the press-to-relieve switch on the fuel system panel. The solenoid valve control circuit is energized and protected by the fuel pump pressure checkout circuit breaker. When the press-to-relieve switch is pressed, the solenoid valve opens; and fuel from the crossfeed manifold is routed through a check valve into the No. 2 main tank.

Fuel Warning System. A red indicator light located adjacent to each external tank fuel quantity indicator is provided to warn the pilot of an unsafe level of fuel in the outboard wing and/or external tanks. The indicating system is controlled by cam-actuated safe level switches contained within the fuel quantity indicators. The switches for the external and outboard wing tanks open the electrical circuit when the fuel quantity in the tanks is above safe level. The switches (for the main tanks) close the electrical circuit when the fuel level in the Nos. 1 and 4 main tanks is above 30 percent of tank capacity and the level in Nos. 2 and 3 main tanks is above 50 percent of tank capacity. A green band on the main tank's fuel quantity indicators designates the range at which the safe level switches open the electrical circuit. Operation of both the left and right wing tank level warning lights is identical. For example, power to the left wing tank level warning light is directed through the safe level switches in the fuel quantity indicators for the external and outboard wing tanks and through the auxiliary tank fuel control switches Nos. 17 and 18 when in the FUEL FEED position. After passing through these four components, the power is directed through the safe level switches in the Nos. 1 and 2 main tank fuel quantity indicators and to the left red indicator light. Since power must pass through one of the main tank fuel quantify indicators, the red warning light cannot glow under any condition when both indicators are in the safe level (green band) range. With the main tanks serviced above the safe level range, the red warning light will glow to indicate an unsafe fuel load (if the external and outboard wing tanks are not serviced to a safe level). The red warning light will glow to indicate unsafe fuel use if either the external tank or the outboard wing tank fuel control switch is placed in the FUEL FEED position while the No. 1 or 2 main tanks contain fuel above safe level. Operation of the right wing tank level warning light is identical.

Exercises (430):

1. In the fuel system, what information is found on the boost pump?

2. What type of valve is generally found as a fire shutoff valve?

3. What type valve is generally found on the auxiliary tank engine feed control?

4. What is the purpose of the fuel level control valve?

5. When you get a steady amber light on the fuel flow indicator, what condition exists?

6. When you get a flashing amber light on the fuel flow indicator, what condition exists?

7. What warning indicates that the main tanks are serviced above the safe level range?

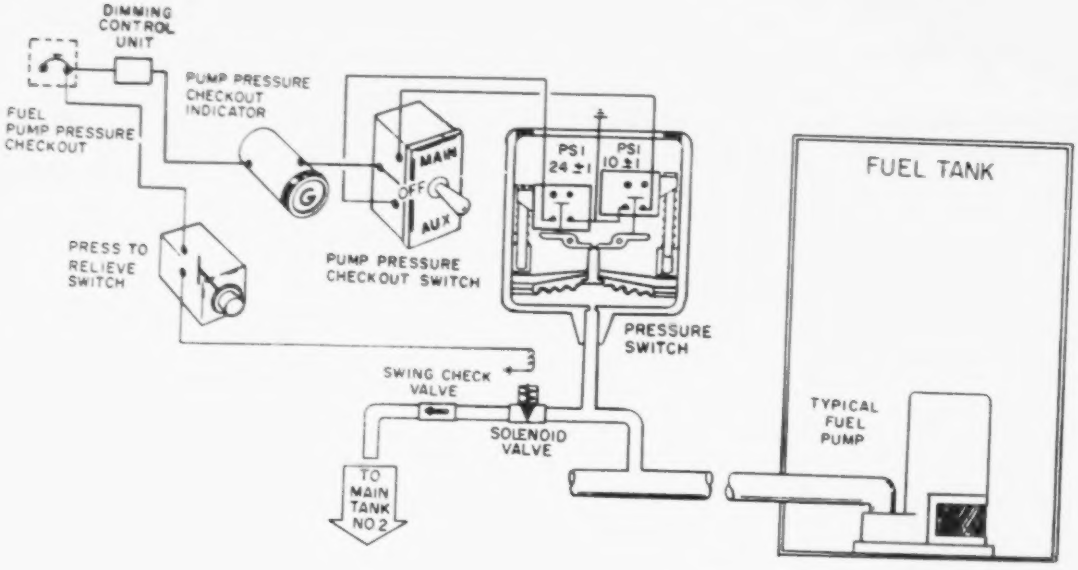

DIMMING CONTROL UNIT
FUEL PUMP PRESSURE CHECKOUT
PUMP PRESSURE CHECKOUT INDICATOR
G
MAIN
OFF
AUX
PUMP PRESSURE CHECKOUT SWITCH
PRESS TO RELIEVE SWITCH
PSI 24 ±1
PSI 10 ±1
FUEL TANK
PRESSURE SWITCH
SWING CHECK VALVE
SOLENOID VALVE
TYPICAL FUEL PUMP
TO MAIN TANK NO 2
42-1791

Figure 3-14. Fuel boost pump pressure checkout system.

431. Identify operating principals of the fuel control system.

Operation of the Fuel Control System. Basic fuel system operation is pretty much the same for all types of aircraft. It is a matter of understanding the correct sequence of operation for each particular type of aircraft. In this section we will discuss various subsystem operations used in the B–52 aircraft. This discussion provides you with the knowledge necessary to determine if the system is functioning correctly.

External power should be connected to the aircraft and engines 1 and 2 started. Main tank No. 1 toggle switch is placed in the ON position. All four boost pumps in tank No. 1 start and supply fuel to engines 1 and 2.

Fuel will be fed directly from the aft body tank to engines 1 and 2 by the use of the following procedure. Locate switch No. 28 on the fuel management panel (see fig. 3-11). On the fact of the switch is an arrow. Place the switch so that the arrow points away from the fuel quantity indicator for the aft body tank. As the switch is turned, the boost pumps in the aft body tank will start and supply fuel pressure to valve No. 13. Place switch No. 13 so that the white line on the face of the switch lines up with the white flow line on the fuel management panel. Fuel will now be fed from the aft body tank to engines 1 and 2.

As the fuel supply in the aft body tank begins to run low, the amber light next to its fuel quantify indicator will begin to flash. This tells the crew that the aft body tank is no longer feeding fuel and should be turned off, and a new tank selected to feed fuel to the engines.

At this point fuel will be fed from the forward body tank to engines 1 and 2. Locate switch No. 25 and turn it so that the arrow points away from the tank. This will cause pumps in the forward body tank to start pumping fuel. Follow the flow line down to switch No. 29. This switch must be turned so that the line on the fact of the switch lines up with the flow line on the management panel (see fig. 3-11). This will cause valve 29 to open and allow fuel to be fed to engines 1 and 2 through valve No. 13, which is already turned to the OPEN position. When the forward body tank fuel flow drops below 850 pounds, the amber light for the forward body tank will flash, indicating that the tank is no longer feeding fuel, and switch No. 25 should be turned off.

Fuel should not be fed from the outboard wings or external tanks unless the main tank quantity indicators are in the green band range. If fuel is pumped from these tanks with main tanks above the green range, the red wing tank warning light will come on, indicating an unsafe wing loading condition. This condition can also be caused during the refuel operation. From this explanation you can see that fuel is routed many ways, depending on the position of the switches located on the fuel management panel. Use the applicable TO when working on the fuel system for information as to component operation and wiring data.

When the aircraft is to be refueled on the ground, the single-point refueling receptacle located in the left forward wheel well is used. With a fuel line connected to the receptacle, the master switch is placed in the ON position and the refuel valve control switch is placed in the OPEN position (see fig. 3-11). This will allow fuel under pressure to enter the refuel manifold. Switch No. 29 must now be placed in the OPEN position (white line on the face of the switch must line up with fuel flow line on the management panel) so that the left wing and aft body tanks can be refueled. Assume that main tank No. 1 is to be refueled. Switch No. 19 must be turned to align the line on the switch with the fuel flow line on the management panel. This will allow fuel flow control valve 19 to open and cause fuel flow to tank No. 1.

When switch No. 19 is operated, power will be applied from the master refuel switch through switch No. 19, then through the fuel quantity indicator, to energize the primary and secondary solenoids in the fuel level control valve, allowing it to open (see fig. 3-12). At the same time, a circuit will be completed through switch No. 19 to the amber light. With the valve open and fuel flowing through the valve into the tank, the amber light will be out. As the tank reaches the full mark, the floats will close their respective ports and fuel pressure will close the valve. The amber light will come on, indicating to the crew that tank No. 1 is full and that switch No. 19 should be closed. The amber light for the main tank does not flash at any time.

To refuel an auxiliary tank, place the switch for the tank to be refueled so that the arrow on the switch points to the quantity indicator for that tank (see fig. 3-11). When the auxiliary tank is full, the valve will close and the amber light will come on, indicating that the tank is full and that switch for that tank should be turned off. It must be remembered at this point that the fuel level control valve will close as a result of a definite weight or volume of fuel and cause the amber light to come on.

With the master refuel switch in the ON position, locate the refuel level checkout switch on the same panel, place it in the PRIMARY position. With fuel pressure in the manifold, select tank No. 2 and place switch No. 20 in the OPEN position. This will cause the primary chamber to flood. The float will then close its port, and fuel pressure will close the valve. The amber light (not shown) will come on, indicating that the primary side of the valve checks correctly (see fig. 3-12). To check the secondary side of the valve, place the refuel level checkout switch in the SECONDARY position. This will cause the secondary chamber to flood. The secondary float will close its port and cause the fuel pressure in the manifold to close the valve. Again the amber light will come on, indicating that the secondary side of the valve is correct.

When external fuel pressure is used to perform the fuel level control valve checkout, it will be necessary to place the refuel valve switch (see fig. 3-11) in the OPEN position. The fuel flow control switches for the external and outboard wing tanks have spring-loaded guards to secure the switches in the OFF position and prevent inadvertent operation. This is necessary because the fuel load in these tanks affects wing loading.

The fuel system is provided with a boost pump pressure checkout circuit to determine that the pump discharge pressure at no-flow for the main tank and auxiliary tank boost pumps is within permissible range. The control switch for the pressure checkout circuit is located on the copilot's side of the forward instrument panel. The switch is a three-position toggle switch marked MAIN, OFF, and AUX. The control switch for the solenoid valve marked PRESS TO RELIEVE is located on the copilot's side of the forward instrument panel. The green pressure check light is located next to switch No. 10 on the fuel management panel and is marked PUMP PRESSURE CHECKOUT.

When the pump pressure checkout switch is placed in the MAIN position and the circuit breakers for pumps 4,6, and 7 are opened, then the control switch for tank No. 1 should be placed in the ON position and switch No. 10 placed to the OPEN position. If pump No. 5 is putting out its rated pressure, the green light will come on (see fig. 3-14).

Two separate fuel scavenge systems are provided to remove fuel trapped in the refuel (cabin) manifold and main manifold after the aircraft has been refueled either by air refueling in flight or single-point refueling on the ground. The cabin manifold is forward of the refuel valve, and the main manifold is returned to main tank No. 2, and main manifold scavenged fuel is returned to main tank No. 3.

The scavenge systems consist of a scavenge pump, shutoff valve, float switch, and a control switch and amber indicating lights located on the copilot's side of the forward instrument panel.

The scavenge pumps are 115-volt AC motor-driven pumps with an output of approximately 2 gallons per minute. The scavenge pump for the cabin manifold is located inside the scavenge system box which surrounds the single-point refueling receptacle in the forward wheel well. The main manifold scavenge pump is located below the center wing tank in the forward side of a fuel and vaportight equipment shroud.

Each fuel scavenge pump is controlled directly by a float switch located in the scavenge drain line. The float switch is an inclosed unit containing a magnetic-type float in a fuel chamber and a single-pole, double-throw, normally open switch in the sealed upper chamber. When the switch closes, the pump control relay should be energized and the scavenge pump will operate, provided the fuel scavenge control switch is in either the CABIN or the MAIN position.

The cabin manifold shutoff valve is located downstream of the float switch in the scavenge drain line. The valve is normally a closed, solenoid-operated, gate-type valve. Operation of the valve is controlled by the adjacent float switch.

The main manifold shutoff valve, located upstream of the float switch, is normally a closed, solenoid-operated, shuttle-type valve. The valve will open when the scavenge system control switch is moved to the MAIN position regardless of the float switch position.

The scavenge system control switch is a three-position switch. The three positions are CABIN, OFF, and MAIN. Placing the switch in the CABIN position should produce no results whatsoever, unless the refuel manifold scavenge float switch contains fuel. If the float switch contains fuel, moving the control switch to the CABIN position will energize the refuel manifold scavenge shutoff valve. The amber FUEL IN MANIFOLD light adjacent to the control switch will come on when the manifold contains fuel (and the master refuel switch is in the OFF position), regardless of the control switch position. The shutoff valve will remain open, the pump will operate continuously, and the light will stay on as long as fuel is present in the float switch or until the scavenge system control switch is moved to the OFF position or the master refuel switch is placed in the REFUEL position.

When the scavenge control switch is placed in the MAIN position, the main scavenge shutoff valve should open regardless of the float switch, and the FUEL IN MAIN MANIFOLD light should come on regardless of whether the main manifold contains fuel or not. A few seconds later, if the main manifold contains fuel, the rising fuel in the float switch float chamber will cause the float switch to close, energizing the pump control relay, which in turn will energize the interlock relay. When this occurs, the scavenge pump will operate continuously. The shutoff valve will remain open and the FUEL IN MAIN MANIFOLD light will stay on until all fuel is removed from the float switch float chamber. When the float chamber is emptied, the float switch contacts open, causing the pump control relay to be deenergized, the shutoff valve to close, and the FUEL IN MAIN MANIFOLD light to go out. To be sure the main manifold is completely scavenged, the scavenge system control switch should be returned to the OFF position to deenergize the interlock relay and then returned to the MAIN position again to cause the shutoff valve to reopen. If the scavenge pump is energized by this action, the pump is pumping fuel away from the float switch faster than gravity flow can refill the float chamber.

The same condition may exist in the cabin refuel manifold scavenge system; however, the recycling will probably occur automatically provided the scavenge system control switch remains in the

CABIN position. In either scavenge system, recycling is undesirable, and the source of difficulty should be located and corrected.

Exercises (431):

1. When refueling the aircraft from the single-point refueling receptacle, what position must the master switch and the refuel valve control switch be placed in?

2. What is the purpose of the boost pump checkout circuit?

3. What is the purpose of a fuel scavenge system?

4. What components make up the scavenge system?

5. What is the output of the fuel scavenge pumps?

6. Each fuel scavenge pump is directly controlled by what switch?

432. Point-out various procedures used in inspecting and troubleshooting the fuel control system.

Inspecting the Fuel Control System. The inspection of the electrical portion of the fuel control system is conducted in the same manner as the inspections performed on the systems previously discussed. Again, inspection workcards are provided to aid and direct you on what to inspect. Make sure that connector plugs are tight, safety wire is installed properly, components are properly fastened to the aircraft, and that the wiring is in serviceable condition.

A good inspection allows you to find and repair an unsafe condition that could cause unnecessary downtime on the aircraft when it is scheduled for a flight. Never limit yourself to those items listed on the inspection workcards. Give it that little bit extra. It will pay off later on.

Troubleshooting the Fuel Control System. A systematic approach to locating a malfunction is called troubleshooting. The majority of your time working on aircraft will be devoted to troubleshooting, so the more proficient you become in locating a malfunction, the easier your job will be.

There are several things that will aid you in becoming a more proficient troubleshooter. The most important is knowing the system and how it operates. You can't learn the system out of tech orders only, you must get out on the flight line and work on the system. The tech order is important, as it gives you specifications, tolerances, torque values, troubleshooting charts, part numbers, and wiring diagrams, just to name a few. The more you know about the system and the more you understand the tech orders, the more proficient you will become, and this is the key. You will develop your own skills in troubleshooting, but this can only come with time.

Let's take a look at a typical fuel pump problem. Refer to figure 3-13 as you go through the circuit. The problem here is that the fuel pump is inoperative. With external electrical power applied, you should start with an operational check. Turn the fuel management switch for the aux. tank to the FUEL FEED position. This will energize the fuel pump relay and direct 115-volt, three-phase AC to the fuel pump. It will also direct 28-volt DC through a dimmer resistor, the amber fuel management indicator light, a flasher when no fuel is flowing, and to ground. If fuel is flowing, the light will be on steady.

After you apply external electrical power, you may notice that the amber light blinks with the fuel management switch in the FUEL FEED position. Thus the malfunction appears to be as previously stated. You can say this because it could be a defective fuel flow switch or a defective fuel pump. At this time you can check the most probable cause, the fuel pump. Turn all power off, remove the connector plug from the fuel pump and reapply power. Check all three phases to ground. Assume you find 115-volt AC on each phase. Therefore, the system is good to this point; again turn power off.

Now check the fuel pump with an ohmmeter. Place one lead on case ground and check each phase. They should all read infinity. If they had a reading, most likely one or more of the circuit breakers would have already popped, so this doublechecks the system for shots. So far all of our checks have given us normal readings.

Now place one lead of the ohmmeter on "A" phase and the other in "B" phase and then "C" phase. Assume you read infinity at this point. Leave the probe in "C" phase and check it to "B" phase. Again you read infinity. This indicates that the phases are open or burnt out, as a reading should have been present and each reading between phases should have been within 10 ohms of each other. The pump, in this case, would have to be removed and replaced. After this has been done, an operational check must be performed to be sure that the system is operating properly. The amber light should now glow steadily when the pump is operated.

As you work on the system over a period of time, you will discover that certain items fail more than others. You can use this knowledge in troubleshooting and it will allow you, in most cases, to go directly to the defective component or area. This can only be learned by working on the system and using a systematic approach in your troubleshooting.

Exercises (432):

1. What guides you on an inspection of the fuel control system?

2. What does the inspection help prevent?

3. When troubleshooting the fuel boost pump with an ohmmeter, what reading should you look for?

433. Identify procedures relative to installation, repairing, modifying, overhauling, and bench checking of components in the fuel control system.

Maintenance. System operation and troubleshooting are a part of the maintenance that is to be done. But in order to better maintain the fuel control system, you must also have knowledge in the other areas of maintenance, which are the installation, repair, modification, overhaul, and bench checking of components. We will briefly look at each of these important functions.

Installing components. All components must be installed on the aircraft in accordance with applicable technical orders. The main reason for this is to make sure proper torque values are used, all connections are made properly, and in the right order. As an electrical systems specialist, about the only installation you will be involved with in the fuel control system will be limited to switches, circuit breakers, and associated wiring. Some fuel pumps have to be wired when they are changed, so this will be your biggest job in this area. Always use a wiring diagram to be sure that it is connected properly.

Repair of components. The repair of components in the fuel control system is extremely limited. With the exception of some very limited repair to the fuel boost pump motors, depending on the maintenance capabilities of your shops, you may never repair any components in the fuel control system.

Modifying and overhauling components. Should a component continue to fail, and upon close examination you find that the same item in that component is the cause of failure, a change will most likely result. This change is called a modification and may be completed during an overhaul or a phased inspection. Also, depending on the urgency, the aircraft may be immediately grounded until the modification is complete.

A modification must be approved by AFSC and is in the form of a TCTO. The TCTO will tell you when, where, and how the modification is to be completed. Any parts needed to complete the modification will be included in a kit that is received with the TCTO. Overhaul of the electrical components in the fuel control system is practically nonexistent as overhaul of these components is either performed by the fuel specialist or at depot-level maintenance.

Bench checking of components. Many electrical shops have the facilities to bench test the submersible fuel pumps after the fuel specialists perform their maintenance on them. They are checked for leaks and operation. Other than checking the pumps for leaks and operation on this tester, no other bench check procedure is performed other than using the ohmmeter to check continuity of the components.

Exercises (433):

1. What do you use to make sure wires are connected properly when working on an installation?

2. By what authority is a modification made on the aircraft components, and who approves them?

3. When is a modification completed?

3-3. Fire and Overheat Warning Systems

FIRE is one of the most dangerous conditions on board an aircraft. Early warning of a fire or overheat condition is instrumental in saving lives. The sooner the pilot and crew are alerted that one of these conditions exist, the sooner they can take the necessary measures to either extinguish the fire or get out of the aircraft.

There are various fire warning and overheat systems utilized in today's aircraft. We will talk about four of them. They are the thermoswitch, thermocouple, photoelectric and the continuous cable. We will also consider a few precautions to observe when working on the various systems.

434. Point out how the fire and overheat warning systems operate and how the tester is used on thermocouples.

Thermoswitch System. In order to detect fires or overheat conditions, detectors are placed in the various zones to be monitored. They are usually placed in the engine and baggage compartments of the more

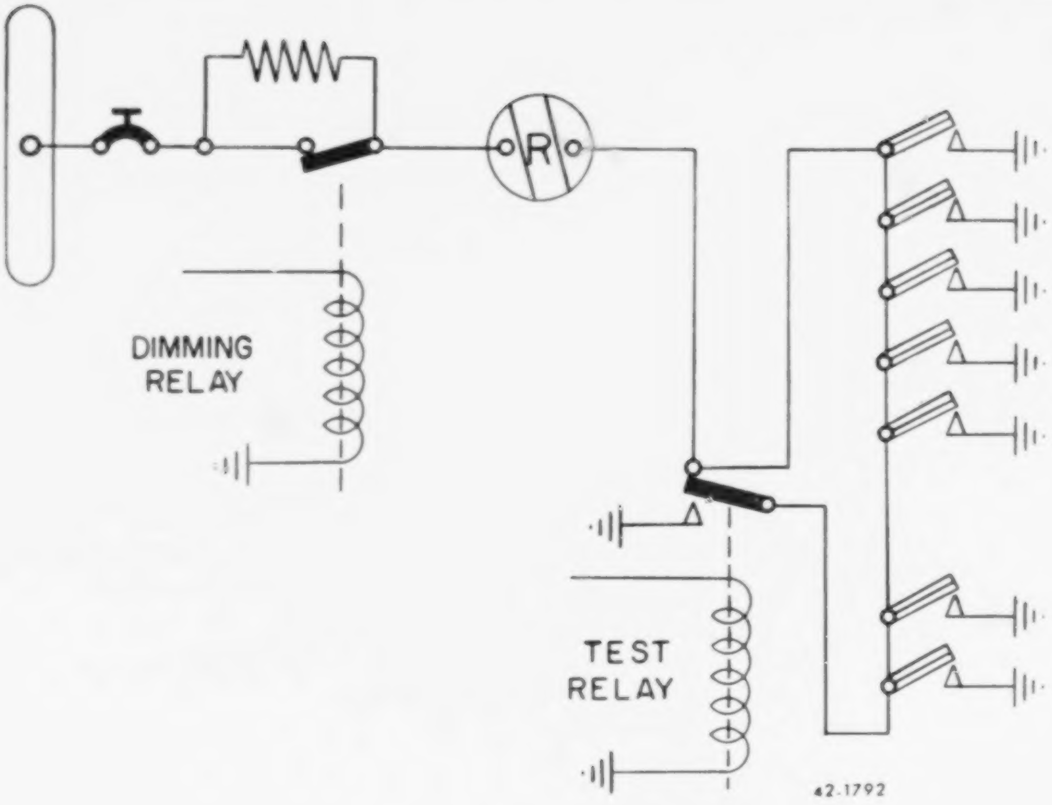


Figure 3-15. Thermal switch circuit.

conventional types of aircraft or in close proximity to the engine section, nacelle, or tail cone of a jet type aircraft.

Thermal switch circuit. The thermal switch type of warning system consists of one or more lights energized from the installation's power supply system and a number of thermal switches that control operation of the light(s). These thermal switches are heat-sensitive units that complete an electrical circuit when they are exposed to a certain temperature. These thermal switches are connected in parallel with each other but in series with the warning light, as shown in figure 3-15. Whenever the heat rises above a certain value in any one section of the installation where the thermal switches are located, the overtemperature fire warning light is illuminated by the closing of the thermal switch. Thus, the thermal switch completes a ground path for current flow. There is no set number of switches required, the exact number being determined by the aircraft designer.

The Fenwal switch is constructed with two silver contacts mounted on, but electrically insulated from, curved nickel-iron struts having a low expansion coefficient. See figure 3-16 for the details of construction of the Fenwal switch. The contact assembly is mounted in a seamless drawn brass or stainless steel tube that has a high coefficient of expansion.

The Iron Fireman switch is constructed with a high-nickel steel rod located along the centerline of the tube, with one end of the rod attached to the opposite end of the tube from the mounting flange. A cross-sectional view of the construction is shown in figure 3-17. The other end of the nickel steel rod presses against a switch blade so that it holds a pair of electrical contacts in an open position. This assembly is mounted in a ventilated stainless steel tube that has a high coefficient of expansion.

When these switches are subjected to heat, both the shell and the internal elements will expand and a subsequent increase in overall length will result. However, the relative increase in the length of the shell, having a high coefficient of expansion, will be much greater than that of the internal elements' assembly. The temperature at which the shell expands lengthwise sufficiently to allow the switch contacts to close is considered the actuating point.

Caution must be observed when handling these units because the shell is the actuating mechanism. The shell should never be handled with pliers or forced into position either by hand or with tools. Before, during, and after installation, precautionary measures must be taken to insure that the shell is not dented, distorted, or otherwise damaged. In addition, caution must be exercised in securing the lockwasher and hex nut on the positive terminal of

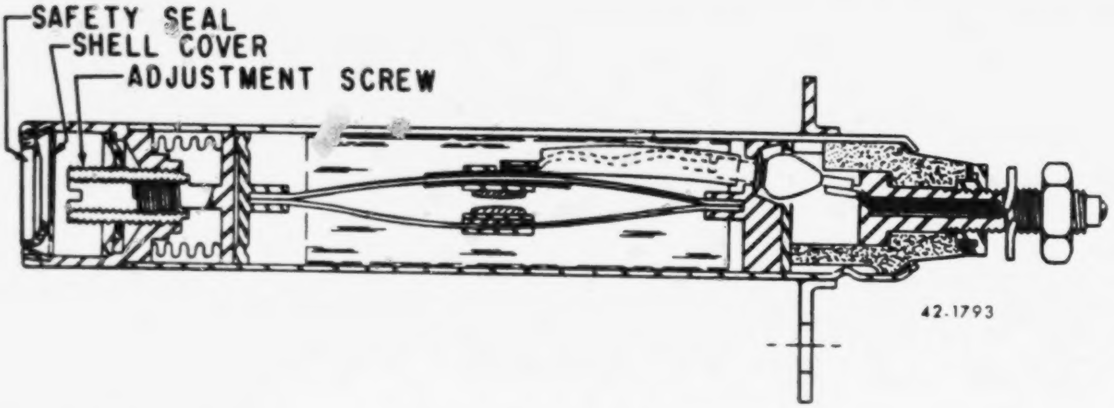


Figure 3-16. Fenwal thermal switch.

the switch. When securing the terminal nut, a torque wrench must be used. Check current tech data for proper torque values.

Upon installation of a new switch, the outer shell will be visually inspected for evidence of any damage which could change the actuating point or prevent the switch from operating. After the switch has been put into operation, it should always be kept free of dirt, dust, oil, grease, or any foreign substance that may accumulate on the switch and change the amount of heat required to actuate it. Different locations on the aircraft require different heat ranges, so be certain that the correct type is installed. The type number of the detector switch can be located on the unit's mounting flange.

Thermal switch testing. Fire and overheat detector switches may be adjusted, by maintenance personnel, to any desired temperature within the unit's range by using one of the authorized calibrators and/or testers available through Air Force supply channels. The following procedures are based on the use of the Fenwal high-temperature test kit, which is a portable testing device designed to provide a convenient method for adjusting or checking the temperature setting of thermal switches. A typical high-temperature test kit is shown in figure 3-18. This tester is designed to provide true thermoswitch temperature settings for units mounted from the top of the tester using the special thermocouple assembly provided to measure temperatures. A thermometer is also provided with this kit. Provisions are also made on this tester to insert thermoswitch units from the bottom of the tester.

Operating temperatures within the range of 800° F. to 1000° F. may be obtained by operating the test unit directly on 115 volts AC. Approximately 20 minutes will be required for the tester to reach 1000° F. when starting from room temperatures.

Operating temperatures in the range of 100° F. to 800° F. may be obtained by using a 115-volt variable voltage transformer having a 115-volt, 500-watt output. The heating time in this case is dependent on input voltage and the temperature desired.

When the thermoswitch unit has been adjusted to room temperature (approximately 70° F.), an approximate temperature setting can be obtained by rotating the adjusting sleeve the proper number of turns for the given unit. The approximate temperature adjustment rate of thermoswitch units can be determined from the applicable technical order.

Exercises (434):

1. Where are detectors normally placed on the aircraft?

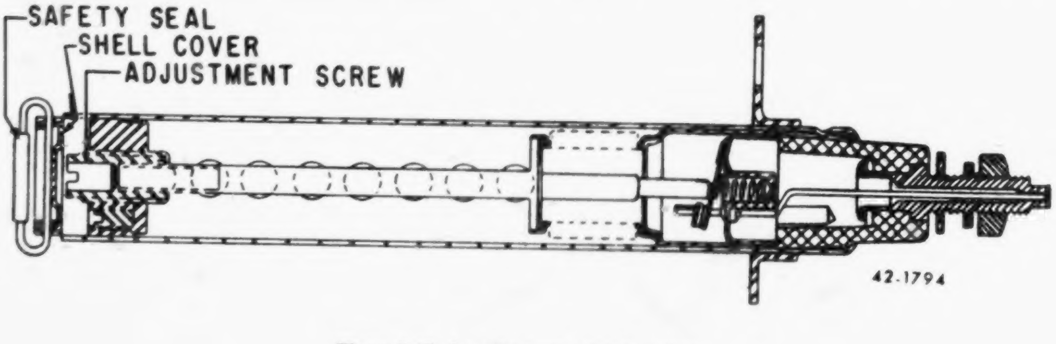


Figure 3-17. Iron Fireman thermal switch.

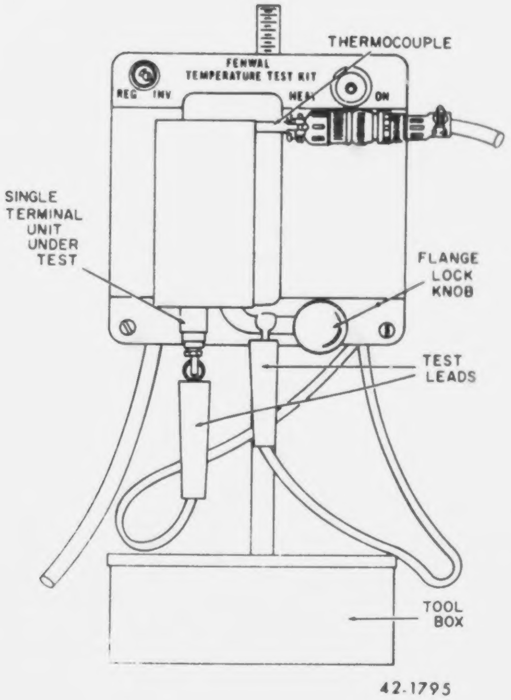

THERMOCOUPLE
FENWAL
TEMPERATURE TEST KIT
REG
INV
HEAT
ON
SINGLE TERMINAL UNIT UNDER TEST
FLANGE LOCK KNOB
TEST LEADS
TOOL BOX
42-1795

Figure 3-18. Test kit with detector inserted from the bottom.

2. How are the thermal switches hooked up in the system?

3. Tell how the thermal switch operates.

4. On what principle of operation does the Fenwal and Iron Fireman type detector switches operate?

5. What precautions must be taken when handling these switches?

6. Can the fire and overheat detector switches be adjusted, and if so, by whom?

435. Cite operating characteristics relative to the operation of the thermocouple fire warning systems and tell how the system is checked.

Thermocouple Fire Warning System. The thermocouple fire warning system operates on an entirely different principle than does the thermal switch type. A thermocouple depends upon the rate of temperature rise and will not give a warning when an engine slowly overheats or a short circuit develops. The system is composed of a relay box, warning lights, and the thermocouples. The wiring of these units can be divided into three circuits: the detector, the alarm, and the test circuit, as shown in figure 3-19.

The relay box contains two relays: the sensitive relay (item B) and the slave relay (item A), as well as the thermal test unit (item C) in figure 3-19. Such a box may contain from one to eight identical circuits, depending on the number of potential fire zones. For example, a four-engine aircraft may use two relay boxes, each of which contains six identical circuits. This aircraft may need 12 circuits if each engine has

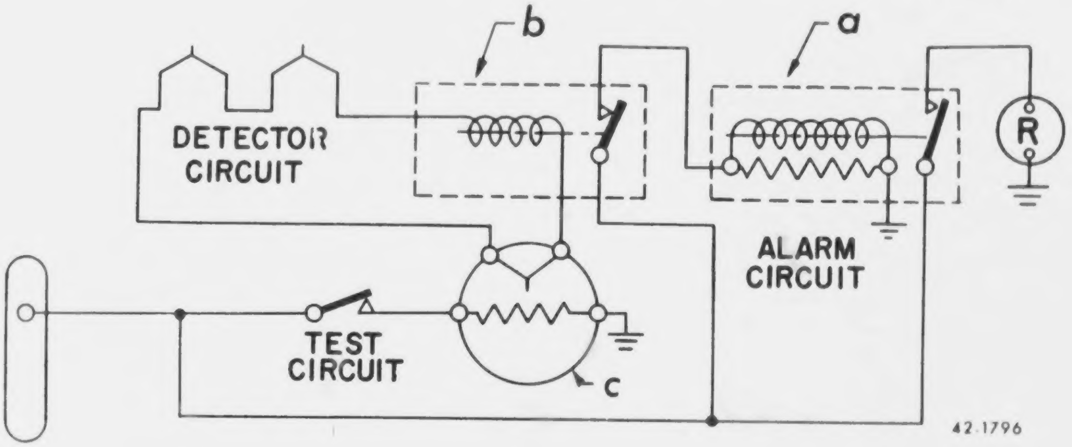

b
a
DETECTOR CIRCUIT
R
ALARM CIRCUIT
TEST CIRCUIT
c
42-1796

Figure 3-19. Thermocouple fire warning circuit.

A. Slave relay
B. Sensitive relay
C. Thermal test unit

three potential fire zones. The warning lights are controlled by the relays and the operation of the relays is regulated by thermocouples distributed throughout the potential fire zones. The fire detector circuit consists of several thermocouples connected in series to each other and with the sensitive relay coil. Figure 3-20 shows a sectionalized view of a typical thermocouple. This device is constructed of two different metals: chromel and constantan. At the point where these metals are joined and are exposed to the heat of a fire, we have what is called a hot junction. The thermocouple also has a reference junction inclosed in a dead airspace between two insulation blocks. Finally, there is a metal cage to provide mechanical protection for the thermocouple without hindering the free movement of air to the hot junction.

As the temperature rises rapidly, the thermocouple produces a voltage because of the temperature difference between the hot junction and the reference junction. If both junctions are heated at the same rate, no voltage will result. In the engine compartment, there is a normal gradual rise in temperature from engine operation; because it is gradual, both junctions heat at the same rate and no warning signal is given. If there is a fire, however, the hot junctions will heat more rapidly than the reference one. The resulting voltage causes a current to flow within the detector circuit. At any time the current exceeds 4 milliamperes (0.004 ampere), the sensitive relay, shown in figure 3-19, will close and complete a circuit between the aircraft power system and the coil of the slave relay. The slave relay then closes and completes the circuit to the warning light, as shown in figure 3-19. The light flashes on and gives a visual indication of fire.

As previously mentioned, the total number of thermocouples used in individual detector circuits depends on the size of the potential fire zone and the total circuit resistance. The circuit resistance should never exceed 5 ohms. As shown in figure 3-19, the circuit has one resistor. The resistor connected across the terminals of the slave relay absorbs the coil's self-induced voltage. This arrangement is for the purpose of preventing arcing across the contacts of the sensitive relay; these contacts are so fragile that they would burn or weld together if arcing were permitted. This is how the elimination process works. When the sensitive relay opens (fig. 3-19), it interrupts the electric circuit to the slave relay and causes the magnetic field which is surrounding the coil to collapse back upon itself. When this happens, the coil will get is voltage through self-induction. Since a resistor is across the coil terminals, there is still a path for current flow as a result of this voltage. The resistor across the coil terminals will then eliminate arcing of the sensitive relay contacts.

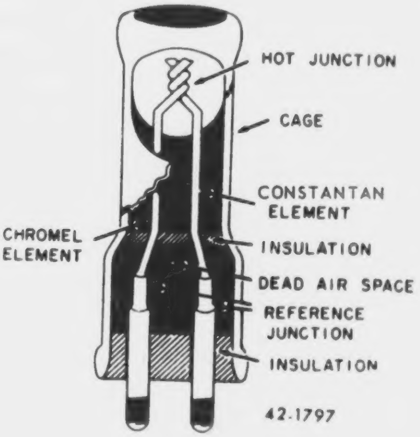


Figure 3-20. Typical thermocouple.

For testing purposes, an electrically heated thermal test unit is heated by operation of the test switch. The heating of this unit furnishes a current in excess of the 4 milliamperes required for operation of the sensitive unit to actuate the system and make the warning light come on.

Polarity check. The polarity of the thermocouples should be checked after a power package change or repair, or following the replacement of assemblies containing all or part of a fire detection circuit. A fire detection system tester or the lowest amperage or voltage scale on the standard milliammeter is usually satisfactory for a polarity check. The positive and negative leads of the meter are connected respectively to the positive and negative leads of the fire detection circuit involved. Check the circuit wiring diagram in the applicable technical order. For the circuits connected to connector plug terminals A and B, C, D, etc., the first lettered terminal is positive and the second terminal is negative, in that order, for all circuits. Using a soldering iron, heat the individual thermocouples and check for meter deflection. Be careful not to ground out the termocouple wiring with the soldering iron. If the polarity is correct, the meter will deflect in a clockwise direction. If meter deflection is counterclockwise, reverse the connections on the thermocouple. The need for a polarity check is very great, because a reversed thermocouple will not only fail to operate the system but it will have a tendency to counteract the output of other correctly connected thermocouples.

Exercises (435):

1. The thermocouple fire detector system depends upon what characteristic of temperature?

2. Name the three items contained in the relay box.

3. How are the thermocouples connected in respect to each other?

4. How does the thermocouple operate in a warning system?

5. How are the thermocouples checked in the system?

6. Why is it important that a polarity check be made of a thermocouple in the system?

436. Cite the test equipment used to test the photoelectric fire detection system and point out operational characteristics.

Photoelectric System. This type of fire detection system uses the varying resistance of a photoconductive cell in the detector unit to originate a fire signal. The detector cell consists of a glass envelope, inside which a coating of infrared sensitive lead sulphide is deposited. The resistance of the deposit changes rapidly when exposed to the radiation emitted by a flame. The resistance of the cell is in series with resistors of a resistance network in the power unit. The network is capacitance coupled to the grid of an input tube of the amplifier section of the power unit. The power supply of the power unit applies a DC voltage across the series resistances. When a flame causes the cell resistance to fluctuate, a pulsing DC signal is fed to the amplifier. The amplifier is sensitive only to signals of a frequency between 7 and 60 hertz. It rejects signals caused by radiation from sunlight and other sources. If the input signal is within frequency range, the amplifier functions to energize the two warning lights through a transformer. The light burns steadily so that the warning signal can be distinguished from an overheat warning, which is usually a flashing light. If the fire is extinguished, the warning lights go out as soon as the flame disappears.

Series limiting resistors in the resistor-mixing network of the power unit are arranged so that an input cable from one detector can be short-circuited or opened without interfering with the proper operation of the other detectors (see fig. 3-21). False signals resulting from moisture are prevented by the use of a special harness for the input cables and by hermetic sealing of the power units. The input cables are also shielded to prevent electrical noise from affecting the system.

The test system makes a complete functional test of the detection system. The test selector switch has positions A through G, corresponding to detectors A through G. A test light is an integral part of each detector. As shown in figure 3-21, operation of the test selector switch merely closes DC circuits to energize these lights. The DC supplied to the lights is pulsed at a frequency rate of 10 hertz by an interrupter type test relay. The detector cells are highly sensitive to a 10-hertz frequency; therefore, they originate a signal in the same manner as if exposed to flame radiation. The test light circuit permits individual testing of each detector. If the test selector switch is positioned at A, for example, each of the lights in the five "A" detectors starts flashing. One "A" detector is located in each nacelle, and one is in the gas turbine compressor compartment; therefore, the lights should come on in all five of the fire emergency handles. The lights in the three gas turbine compressor detectors operate when the switch is positioned at "A," "B," and "C." The test checks continuity of circuits, operation of the individual detectors, and operation of the five power units all at one time.

On some aircraft, a master fire warning panel, located on the pilot's instrument panel, has been added to the fire detection system. This panel was added so that a more noticeable warning signal would be given in case of a fire or overheat condition. The signal from a fire detector is transmitted to a power unit in the same manner as that just discussed. The power unit then energizes a relay which closes a circuit from a fire warning lights circuit breaker on the copilot's cicruit breaker panel to lights in the fire emergency handle and the master fire warning panel. The master fire warning panel is common to all five fire detection systems and is energized when any detector produces a warning signal or when the fire detector system test switch is operated. A press-to-test feature is incorporated on the master fire warning light. When the master fire warning light comes on, the fire emergency handles must be checked to determine the location of the fire or overheat condition.

Testing. A Fireye tester with an oscilloscope or VTVM may be used to help isolate troubles in defective fire detection system circuits of the photoelectric type. The tester provides easy access to the power unit and detector circuit so that flight line maintenance personnel can check the fire detector circuit for continuity and sensitivity.

Operational use of this tester is to determine detector system operation capabilities. A detector output signal on the oscilloscope is determined after selecting a detector position with the test switch on the fire emergency control panel and turning the selector switch on the tester to the same detector position. To check the detector circuit for electrical interference, leave the test switch on the fire emergency control panel in the NORMAL position. Select a detector position with the tester selector switch. Check the detector cable for electrical interference by gently flexing the cable at each connector while watching

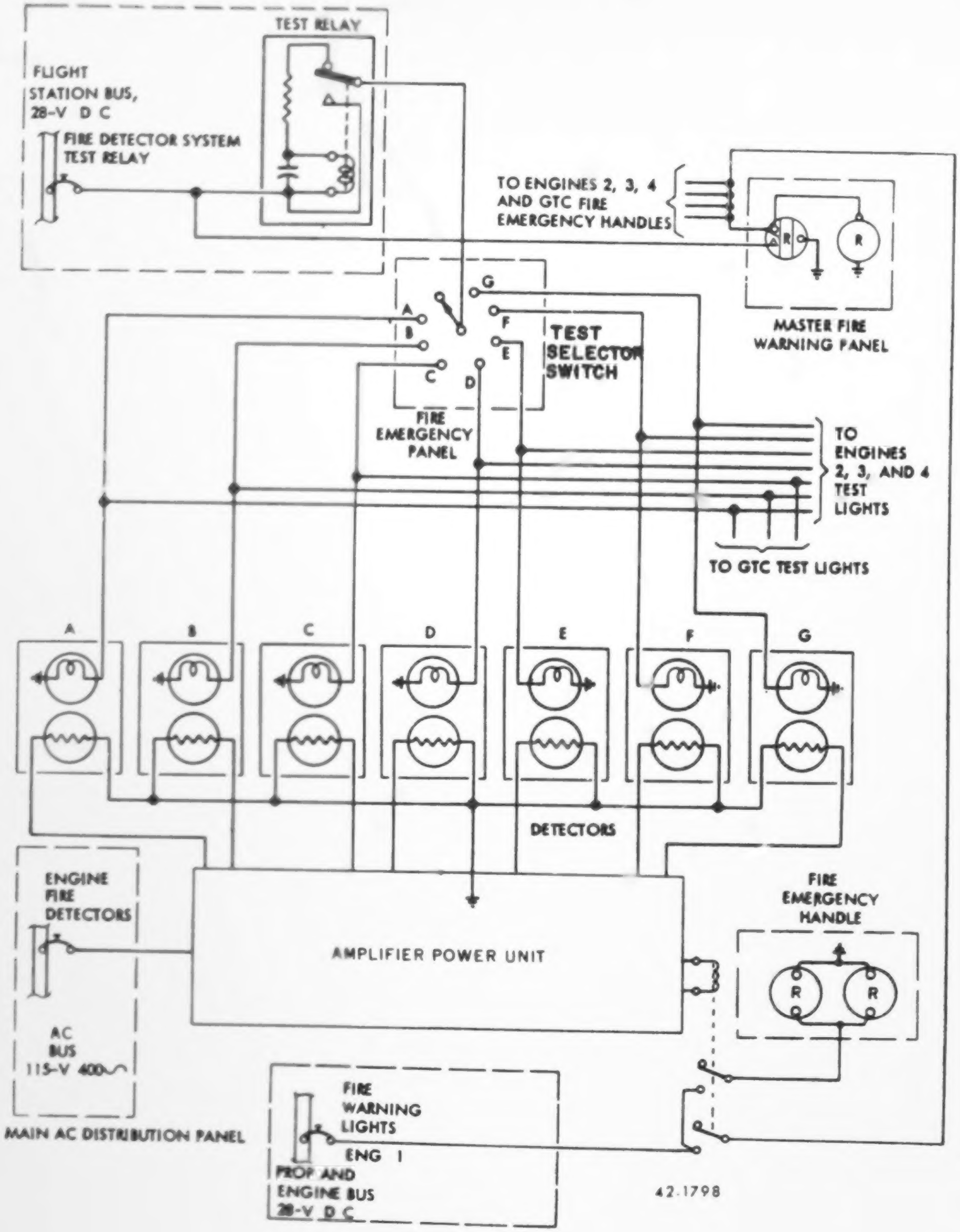

TEST RELAY
FLIGHT STATION BUS, 28-V D C
FIRE DETECTOR SYSTEM TEST RELAY
TO ENGINES 2, 3, 4 AND GTC FIRE EMERGENCY HANDLES
R
R
MASTER FIRE WARNING PANEL
A
B
C
D
E
F
G
TEST SELECTOR SWITCH
FIRE EMERGENCY PANEL
TO ENGINES 2, 3, AND 4 TEST LIGHTS
TO GTC TEST LIGHTS
A
B
C
D
E
F
G
DETECTORS
ENGINE FIRE DETECTORS
AC BUS 115-V 400∿
MAIN AC DISTRIBUTION PANEL
AMPLIFIER POWER UNIT
FIRE EMERGENCY HANDLE
R
R
FIRE WARNING LIGHTS
ENG 1
PROP AND ENGINE BUS 28-V D C
42-1798

Figure 3-21. Photoelectric circuit.

the oscilloscope or VTVM for signs of interference. Interference will appear on the oscilloscope as sharp spikes of irregular length and frequency. Noise will appear on the VTVM as rapid movements of the pointer.

Exercises (436):

1. At what frequencies will the amplifier function?

2.. How is the fire warning light distinguished from the overheat light?

3. What test equipment is used to help isolate troubles in a defective fire detection system?

4. To check the detector circuit for electrical interference, you should leave the test switch on the fire emergency control panel in which position?

437. Cite facts relative to the operation of the continuous cable fire detection circuit and tell how it is tested.

Continuous Cable System. The continuous cable circuit fire detector system may consist of two sensing loops in each nacell: one forward, which is installed in the vicinity of the bleed air ducts and between the tailpipe and the shroud. A separate fire detector control is provided for each sensing element loop. Test relays, flasher units, and control boxes serve to interupt the signals from the nacelle detector system and the gas turbine unit (GTU) fire detector system. The warning signal is then conducted to the indicator lights in the handle of the ENGINE OVERHEAT & FIRE CONTROL switches, and to the master fire warning lights. A flashing signal on these lights indicates an overheat condition, and a steady continuous illumination indicates a fire condition.

The fire detector sensing loops are made up of segments installed around the cowl and the shroud. These segments consist of a center conductor imbedded in a semiconducting compound and inclosed within a tube. The outer tube is bonded to ground, and the resistance between the center conductor and the grounded tube forms one leg of a balanced bridge circuit in the bridge unit. The semiconducting compound has a negative temperature coefficient; that is, as its temperature rises, its resistance decreases. A fire in the nacelle will cause the resistance of this compound to decrease, and the current will flow from the center conductor to ground in the sensing loop. When a fire occurs, the rise in ambient temperature causes an unbalanced bridge circuit, as shown in figure 3-22, and the resulting current flow actuates a relay in the bridge unit, completing the circuit to illuminate the master fire warning light and the warning light in the control switch handle.

When the test switch, also shown in figure 3-22, is placed in the test position, it completes the circuit to actuate the fire detector test relay and ground out the detector loop. This creates an unbalanced bridge circuit, illuminating the fire warning lights.

Consider now the relationship of the continuous cable circuits in a four-engine aircraft. For reasons of simplicity, figure 3-22 shows only one such circuit. In a four-engine aircraft, there may be four fire detection cable assemblies, one for each engine. Each cable assembly consists of a number of sensing elements connected in series with each other. The cables used in each engine nacelle may contain nine series-connected sensing elements. Each cable assembly is routed through its respective engine nacelle and around the engine, following a path where fire is most likely to occur. Each sensing element consists of two Inconel wires incased in a temperature-sensitive ceramic material. The ceramic material is the dielectric which insulates the wires from each other at normal temperatures. One of the wires is connected to a source of DC power in a control unit assembly, and the other wire is grounded to the connector fittings at each end of the sensing element. The wires and ceramic material are incased in a shield made of Inconel, which is a good heat conductor. When a fire occurs in one of the engine nacelles, the resulting temperature rise causes the electrical resistance of the ceramic material to decrease. The decrease in resistance permits a small current to flow between the two wires and to ground.

Each of the four fire detection control assemblies contains a single-pole, single-throw relay, and a three-transistor relay control circuit. It is then connected to its respective fire detection cable, fire pull switch, and a source of 28-volt DC power. When a fire occurs in one of the engine nacelles, the current flow to ground causes a switching action in the three-transistor relay control circuit and closes the relay. When the relay inside the control assembly closes, a circuit is completed between the 28-volt DC power distribution panel and the warning lamp in the handle of the fire pull switch, causing the lamp to light. Activating the fire pull switch, also shown in figure 3-22, closes the fuel and hydraulic valves and stops the flow of combustible liquids to the engine.

The fire detection test switch is a pushbutton type switch. When this switch is pressed, a circuit is completed between the 28-volt DC power distribution panel and the actuating coil of the fire detection test relay. The fire detection test relay is a four-pole, double-throw relay. Each set of relay contacts is connected to its respective fire detection cable assembly and fire detection control assembly. When

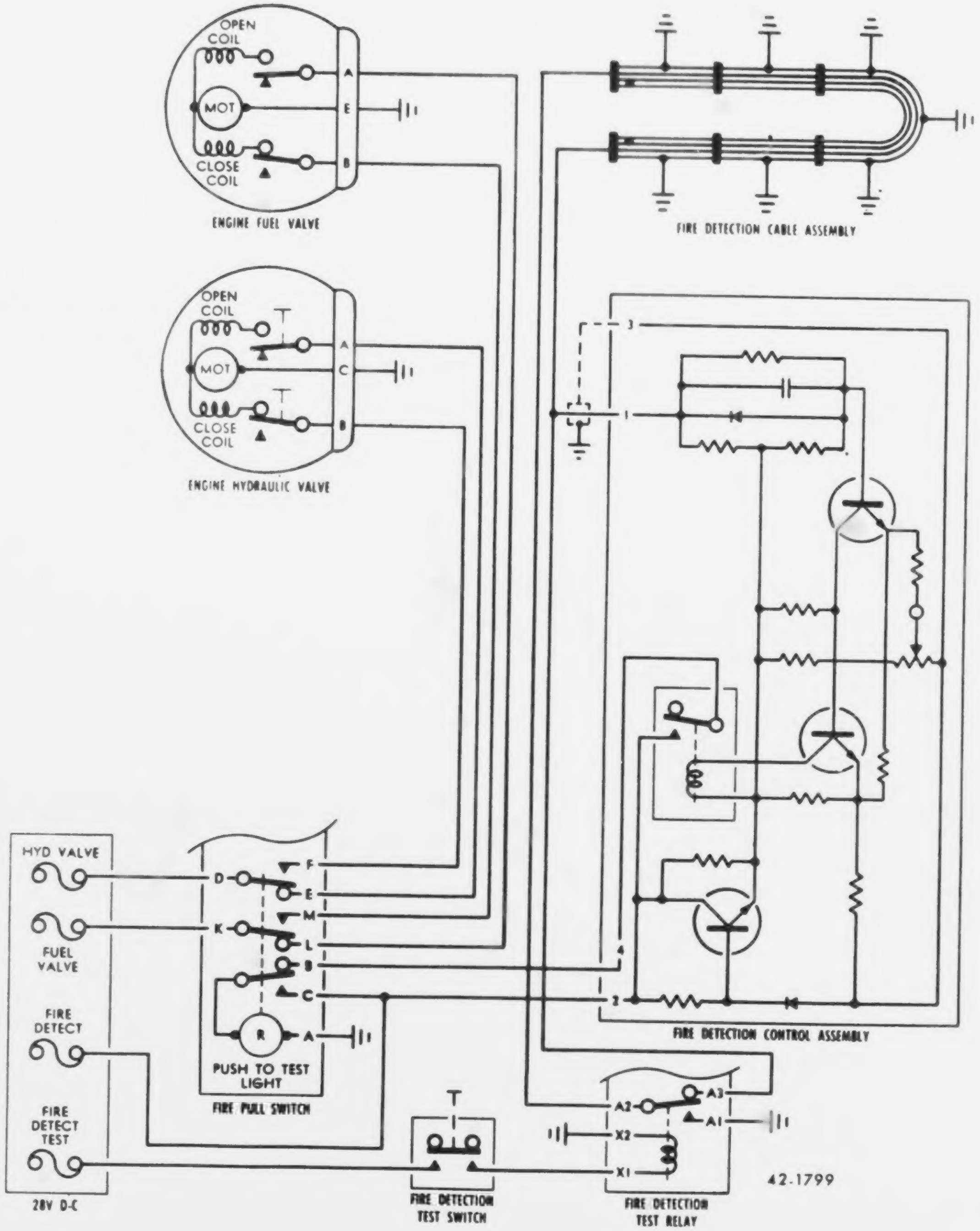

OPEN COIL
MOT
CLOSE COIL
A
E
B
ENGINE FUEL VALVE
FIRE DETECTION CABLE ASSEMBLY
OPEN COIL
MOT
CLOSE COIL
A
C
B
ENGINE HYDRAULIC VALVE
3
1
4
2
FIRE DETECTION CONTROL ASSEMBLY
HYD VALVE
FUEL VALVE
FIRE DETECT
FIRE DETECT TEST
28V D-C
D
K
F
E
M
L
B
C
R
A
PUSH TO TEST LIGHT
FIRE PULL SWITCH
T
FIRE DETECTION TEST SWITCH
A2
A3
A1
X2
X1
FIRE DETECTION TEST RELAY
42-1799

Figure 3-22. Continuous cable circuit.

the relay is energized, the cable assembly in each engine nacelle is grounded to simulate an excessive heat condition to its respective control unit assembly. The warning lamp in each of the four fire pull switches will come on to indicate satisfactory control unit operation and continuity through each cable assembly (see fig. 3-22).

Testing. Operational checkout of the continuous cable detection system is conducted in two parts: (1) the system checkout, and (2) the cable assembly checkout. The system checkout is conducted each time a component of the system is replaced. The cable assembly checkout is conducted when a cable assembly is suspected of having had its resistance value changed. This change of resistance is caused by the cable assembly getting bent or kinked. The checkout is conducted with the aid of a megger.

Exercises (437):

1. How does the sensing loop in a continuous fire warning system operate?

2. How are cable assemblies connected in respect to each other?

3. How are the cable assemblies tested to determine if they are serviceable or not?

4. Name the two parts of the operational checkout of the continous cable detection system.

3-4. Warning Systems

This section covers two kinds of warning systems: The master warning and caution system and the takeoff warning system. The master warning and caution system, normally referred to as master caution, provdes the aircrew with a visual indication of an aircraft system in an abnormal condition. Two kinds of signals are furnished: (1) the master warning and (2) the individual warning signals. The master caution lamp provides a yellow signal, while the individual signals are displayed in red.

The master caution system is equipped with a ground protection feature that automatically prevents unnecessary ground operation of the lamp assemblies by opening the lamp ground circuits when external power is applied to the airplane. An override switch is provided to override the ground protection circuit when it is necessary to have the master caution system in operation.

The takeoff warning system is much simpler to understand and maintain. Its primary purpose is to warn the pilot that the aircraft's flight controls are not configured for takeoff.

438. Cite operational characteristics of the master warning and caution system.

Operation of the Master Warning and Caution System. Both the individual lamp assembly and the master lamp assembly contain lamps that are connected in parallel. The two lamp assemblies are connected directly to a source of 28-volt DC power. The 28-volt DC circuit to ground is completed through the switching action of two transistors, which are an integral part of each master lamp assembly, as shown in figure 3-23. The two lamp assemblies are identical except for the different colored filters and the addition of a time-delay circuit within the master lamp assembly. The time-delay circuit causes the master lamp to light in approximately 1 second after the individual caution lamp assembly has been lighted.

The light test relay, as shown in figure 3-23, is actuated by pressing the MALFUNCTION AND INDICATOR LIGHTS (TEST) SWITCH. When the relay is actuated, a circuit is completed between 28-volt DC and each of the individual lamp assemblies. When this circuit is completed, both master lamp and each individual lamp assembly are lit. If external power is being applied, the warning and caution override switch must be in WARNING AND CAUTION INDICATOR GROUND CHECK position before the lamps will light.

There are two single-pole, single-throw autoreset switches shown in figure 3-23. The switch contacts close when the variacs, which house the switches, are rotated approximately 25° clockwise from the OFF position. The two switches are connected in series with each other.

The MALFUNCTION AND INDICATOR LIGHTS (DIMMING) switch is a single-pole, double-throw, spring loaded switch. The switch is held in a neutral position by the spring-loading feature. When the switch is momentarily placed in the DIM position, dimming relay B is momentarily actuated. If the two autoreset switches are closed, the relay remains actuated after the dimming switch returns to the neutral position. When the dimming switch is momentarily placed in the BRIGHT position, a ground is established which causes the actuating current to bypass the dimming relays and both relays are deactuated.

The MALFUNCTION AND INDICATOR LIGHTS (TEST) switch is the push-to-make type switch. When the switch is pressed, a circuit is completed between 28-volt DC and the actuating coil of the light test relay. When this circuit is completed, the light test relay is actuated (see fig. 3-23).

Fault switches are assorted types of switches or circuit-closing devices in the master warning and caution system. They are used to indicate malfunctions in various locations in the aircraft, such as in the anti-ice, fuel pumps, oil low, AC generator, hydraulic pumps, or canopy unlock components.

Dimming relays A and B are actuated by momentarily placing the malfunction and indicator light dimming switch in the DIM position. If the panel variacs (autoreset switches) are both rotated 25° clockwise from the OFF position, the relays will hold in the actuated position after the dimming switch has returned to neutral position. When the relays

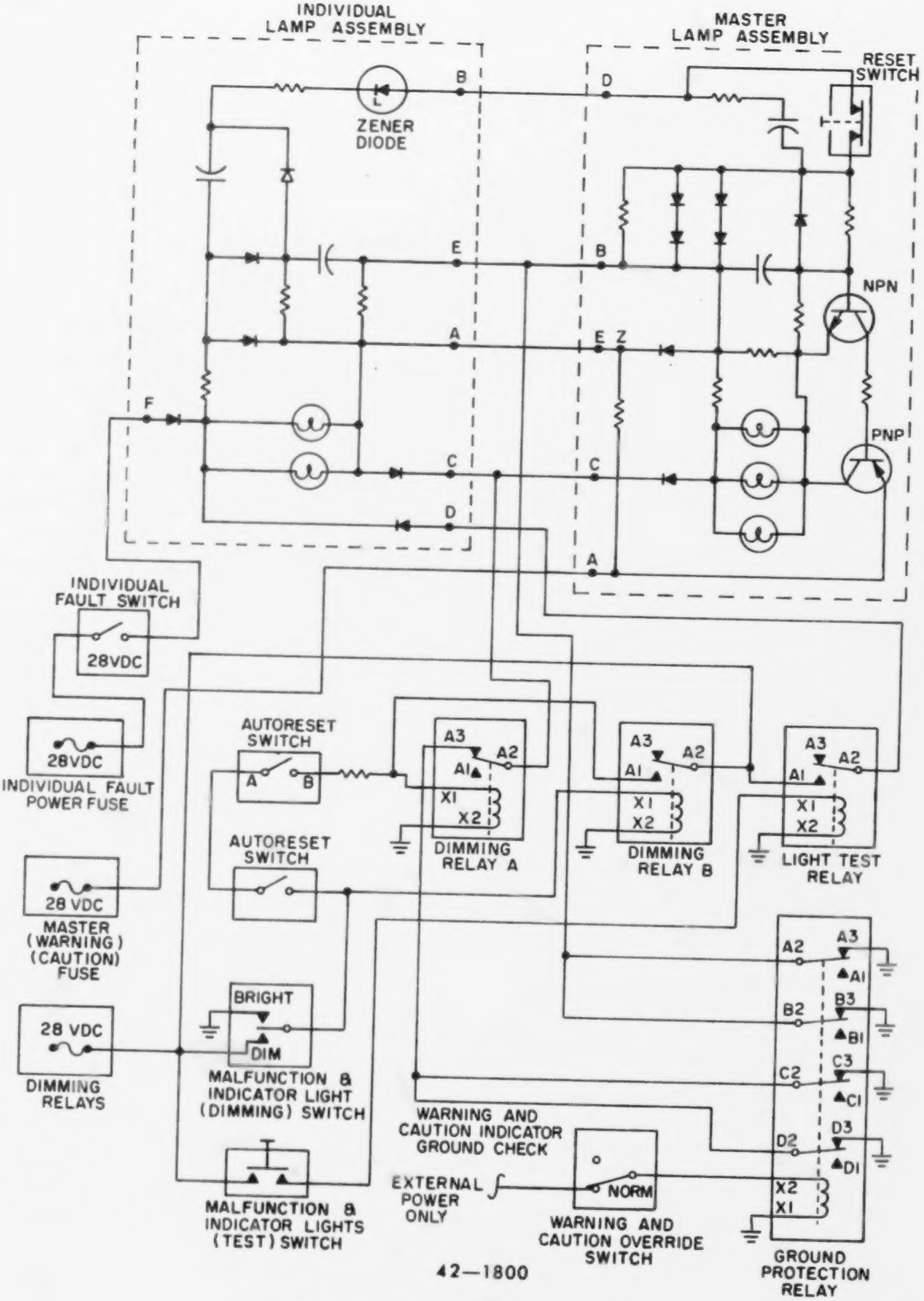

INDIVIDUAL LAMP ASSEMBLY
MASTER LAMP ASSEMBLY
RESET SWITCH
ZENER DIODE
NPN
PNP
B
D
E
B
A
E
Z
F
C
C
D
A
INDIVIDUAL FAULT SWITCH
28VDC
28VDC
INDIVIDUAL FAULT POWER FUSE
AUTORESET SWITCH
A
B
AUTORESET SWITCH
A3
A2
A1
X1
X2
DIMMING RELAY A
A3
A2
A1
X1
X2
DIMMING RELAY B
A3
A2
A1
X1
X2
LIGHT TEST RELAY
28 VDC
MASTER (WARNING) (CAUTION) FUSE
28 VDC
DIMMING RELAYS
BRIGHT
DIM
MALFUNCTION & INDICATOR LIGHT (DIMMING) SWITCH
MALFUNCTION & INDICATOR LIGHTS (TEST) SWITCH
WARNING AND CAUTION INDICATOR GROUND CHECK
EXTERNAL POWER ONLY
NORM
WARNING AND CAUTION OVERRIDE SWITCH
A2
A3
A1
B2
B3
B1
C2
C3
C1
D2
D3
D1
X2
X1
GROUND PROTECTION RELAY
42—1800

Figure 3-23. Master warning and caution system.

are actuated, the ground is removed from each of the lamp assemblies. The lamps within each lamp assembly must then find ground through individual resistors connected in series with each lamp and ground. The lamps dim as a result of the voltage drops across each of the resistors.

The master warning lamp assembly, also shown in figure 3-23, consists of an airtight container with a red filter faceplate, three parallel-connected light bulbs, and the required circuits to connect the light bulbs to a source of 28-volt DC power. The master warning lamp assembly is lighted when any individual warning lamp illuminates. This indicates trouble has developed within its system. When the master warning lamp assembly is lighted, the words MASTER WARNING PUSH TO RESET appear in red letters on the face of the filter. When the master warning lamp assembly is pushed, the lamp goes out and remains out until a different individual warning lamp signals trouble within its system.

Each individual warning lamp assembly consists of an airtight container with a red filter faceplate, two parallel-connected light bulbs, and required circuits to connect the light bulbs to a source of 28-volt DC power. When an individual warning lamp assembly is lighted, the callout of the system in which trouble has developed appears in red letters on the face of the filter. The lamp remains lighted until the trouble within its system has been corrected.

The master lamp assembly consists of an airtight container with a yellow filter faceplate, three parallel-connected light bulbs, and required circuits to connect the light bulbs to a source of 28-volt DC power. The master caution lamp assembly is lighted approximately 1 second after any one of the individual caution lamp assemblies signals that the trouble has developed within its system. The time-delay feature and the yellow filter are the only differences between the master caution lamp assembly and the master warning lamp assembly. When the master caution lamp assembly is lighted, the words MASTER CAUTION PUSH TO RESET appear in yellow letters on the face of the assembly. When the master caution lamp assembly is pushed, the lamp goes out and remains out until a different individual caution lamp signals trouble within its system.

The individual caution lamp assemblies are identical with the individual warning lamp assemblies, except for the color of the filter. When an individual caution lamp assembly is lighted, the callout of the system in which trouble has developed appears in yellow letters on the face of the assembly.

The warning and caution override switch, shown in figure 3-23, is a two-position (WARNING AND CAUTION IND GROUND CHECK and NORM) switch, located in the ground protection circuit between the external power source and the closing coil of the ground protection relay. When the override switch is in the NORM position, the closing coil circuit is completed and the lamp ground circuits are open. When the override switch is in the WARNING AND CAUTION IND GROUND CHECK position, the closing coil circuit is open and the lamp ground circuits are completed.

The ground protection relay (fig. 3-23) is used to open the ground circuits for the master warning and caution system lamps when external power is applied to the airplane. The power for the closing coil of the relay, supplied by the external power unit, is routed through the ground protection override switch. The ground protection relay is deenergized to complete the ground circuits for the lamps when the aircraft is furnishing its own electrical power or when external power is being furnished to the aircraft and the ground protection override switch is placed in the WARNING AND CAUTION IND GROUND CHECK position.

When trouble develops within an aircraft system, the fault switch closes. A circuit is completed from the 28-volt power distribution panel through the fault switch, through terminals F and C of the individual lamp assembly, and through the normally closed contacts of the dimming relays to ground (see fig. 3-23). When this circuit is complete, the individual lamp assembly is lighted.

Each individual lamp assembly includes a tripping circuit that controls the voltage to the associated master lamp. The tripping circuit allows voltage to be applied to the master lamp when a fault occurs in the airplane system being monitored by the light. The tripping circuit maintains the application of voltage to the master light until the fault is cleared or the master light is pushed to the RESET position.

When a fault voltage is applied through the individual lamp to the master lamp, the transistor switching circuit in the master lamp allows voltage from the applicable master fuse in the 28-volt power distribution panel to light the master lamp (see fig. 3-23).

When the master lamp assembly is pushed to the RESET position, a momentary type of switch in the master lamp opens the circuit from the individual lamp, and the tripping circuit in the individual lamp prevents reapplication of voltage to the master lamp until a fault develops within another system. When another fault occurs, the cycle will be repeated.

When the MALF & IND LIGHTS (TEST) switch it pressed, the light test relay is actuated. This completes a circuit from the 28-volt power distribution panel through the light test relay contacts to terminal D of each individual lamp assembly. From terminal D to ground the circuit is the same as the circuit to which power is furnished through the fault switch. The master warning lamp assembly, the master caution lamp assembly, and each of the individual lamp assemblies are lighted when this circuit is completed (see fig. 3-23).

Exercises (438):

1. How are the lamps in the master caution and warning light assemblies connected to each other?

2. How long after an individual caution lamp comes on will the master caution lamp come on?

3. When do the autoreset switches close?

4. What are the two conditions in the master warning and caution system under which the master warning lamp will go out?

439. State the purpose of the takeoff warning system.

Takeoff Warning System. The takeoff warning system monitors various systems in the aircraft. When the aircraft is ready for flight, a green light will come on. This light is located on the instrument panel. It indicates that the various systems monitored by the takeoff warning systems, such as the doors, spoilers, thrust-reversers, flaps, and horizontal stabilizer, just to name a few, are ready for takeoff. The number of circuits monitored by the takeoff warning depends on the aircraft. Naturally, a larger aircraft will have more systems providing inputs than a smaller aircraft. As long as all the systems monitored remain in the proper position, the green takeoff warning light will remain on until the gear is retracted, at which time it will go out. Also, the autopilot must not be engaged before the takeoff light comes on.

Exercise (439):

1. What is the purpose of the takeoff warning system, and what color is the indicator light?

440. Point out procedures to be followed in order to properly maintain the warning systems.

Maintenance. In order to better maintain the electrical portion of the warning systems, you must also be able to perform numerous maintenance functions. These include installing, repairing, modifying, overhauling, and bench checking components. There are some warning systems that are designed and built in such a way that only limited maintenance can be performed on them. In these systems, you will be limited to merely checking light sockets with an ohmmeter. However, other warning systems, such as the master caution warning system, contains a control box that can be repaired. Since it can be repaired, a special bench tester was developed to check it. So, after the malfunctions in the control box have been located and repaired, the box will be tested for proper operation.

There are several types of testers utilized on the aircraft and in the shop to test thermocouples. Two of these testers, namely the thermoswitch tester and the jetcal tester, were discussed in Volume 2.

Anytime components are installed, care must be taken to install them in accordance with current technical data. Extreme care must be taken when installing fire and overheat detectors since their sensitivity can be greatly affected through rough handling and poor maintenance. A kink or dent in the continuous cable will change the resistance of the cable, so if you accidently bend or dent one, don't try to straighten it out; replace it with a new one. The thermocouples are also subject to damage. The outer case should never be tightened with a wrench as a wrench could dent the case, causing its internal circuit to become shorted out. So if you dent one or discover one that is dented, replace it with a good one.

Should you be assigned to modify a component or system, you will be supplied with all the necessary parts to complete this modification in the form of a TCTO kit. The TCTO will tell you when, where, and how the modification should be completed.

Anytime you complete a project on the aircraft or a component of the aircraft, an important function must be performed before the aircraft or component is ready for use. This is the operational check. Even if you only replaced a light bulb, the system cannot be considered operational until it is checked out.

Exercises (440):

1. After a component is repaired, what is the next thing that is done with it?

2. If you install a continous cable and accidently bend it, what should you do?

3. Where do you get the parts and authority to perform a modification?

Utility Systems

LIGHTS on an aircraft are used for various purposes. They are used to attract attention so you can be seen, to light an area outside the aircraft as an aid in landing, to light the instrument and control panels, or to flood an interior area with light. These lights are divided into two groups: interior and exterior lighting. We will discuss each group and point out various maintenance functions.

We will also discuss the Nesa anti-icing system. Many times, fog, or fog and ice, forms on the windows in the cockpit. The Nesa anti-icing system will keep them clear. Maintenance of the system is important, so we will point out troubleshooting and other maintenance related functions.

4-1. Lighting Systems

The majority of lighting components, circuits, and operation are basically the same for most aircraft. There are a few special lighting systems that pertain only to certain aircraft. These will not be covered in this CDC. These systems are either covered through an FTD or a training session in the shop.

This section covers the operation, inspection, troubleshooting, and other related maintenance functions. First consider the interior lighting system and then discuss the exterior lighting.

441. Give the purpose and operational characteristics of the interior lights.

Operation of Interior Lights. The types and numbers of interior lighting systems vary from one type of aircraft to another. Small aircraft, such as fighters, have instrument lights, panel lights, white and red floodlights, and a portable spot and floodlight. Larger aircraft, such as bomber and cargo planes, have several other interior lighting systems. These include entrance and aisle lights, walkway and crawlway lights, bomb bay lights in bombers, or cargo bay lights for cargo-type aircraft. The necessary panel and instrument lights are installed at each crewmember's station.

Instrument lights. Lights that are used to illuminate instruments may be divded into two groups, primary lights and secondary lights. The primary lights consist of individual lights located inside the hoods to provide illumination for one particular instrument. Included with primary lights are edge lights, which illuminate the lettering on the control and circuit breaker panels. These lights are mounted in the plastic panels so that the light radiates only through the plastic. The panels are painted with a black vinyl lacquer. Lettering on the panel is etched through the lacquer so that the light radiating through the plastic makes the lettering easy to read. The secondary lights are floodlights that provide light for the instruments when the primary system fails.

A simplified schematic of a typical instrument lighting circuit is shown in figure 4-1. Notice that the system is powered by 115-volt AC. The 115 volts is reduced by a variable transformer (console lights control) which maintenance personnel often refer to as a Variac. The CONSOLE LIGHTS CONTROL permits the voltage to be varied from zero to 28 volts. From the wiper arm of the variable transformer, you will notice the power is applied to the EDGE LIGHTS, the STANDBY COMPASS light, the auto-transformer that supplies the integral instrument lights, the pilot's left utility panel, the instrument panel emergency floodlights switch, and the pilot's right utility and circuit breaker panel.

If the instrument light circuit fails, the pilot can still use the left and right console floodlights and the instrument panel emergency floodlights. The circuit for these lights is shown in figure 4-2. This figure illustrates a typical circuit, but it may be quite different from circuits with which you are familiar. The SPDT (single-pole, double-throw) SWITCH, which is mechanically connected to the wiper arm of the CONSOLE LIGHTS CONTROL variable transformer, is actuated whenever the CONSOLE LIGHTS CONTROL is moved from the OFF position. Therefore, the LEFT and RIGHT CONSOLE RED FLOODLIGHTS are on whenever the SPDT SWITCH is on. The pilot can switch them from dim to medium or bright. When they are switched to the DIM position, they have 7.5 volts applied. When they are switched to MED, they are connected to a

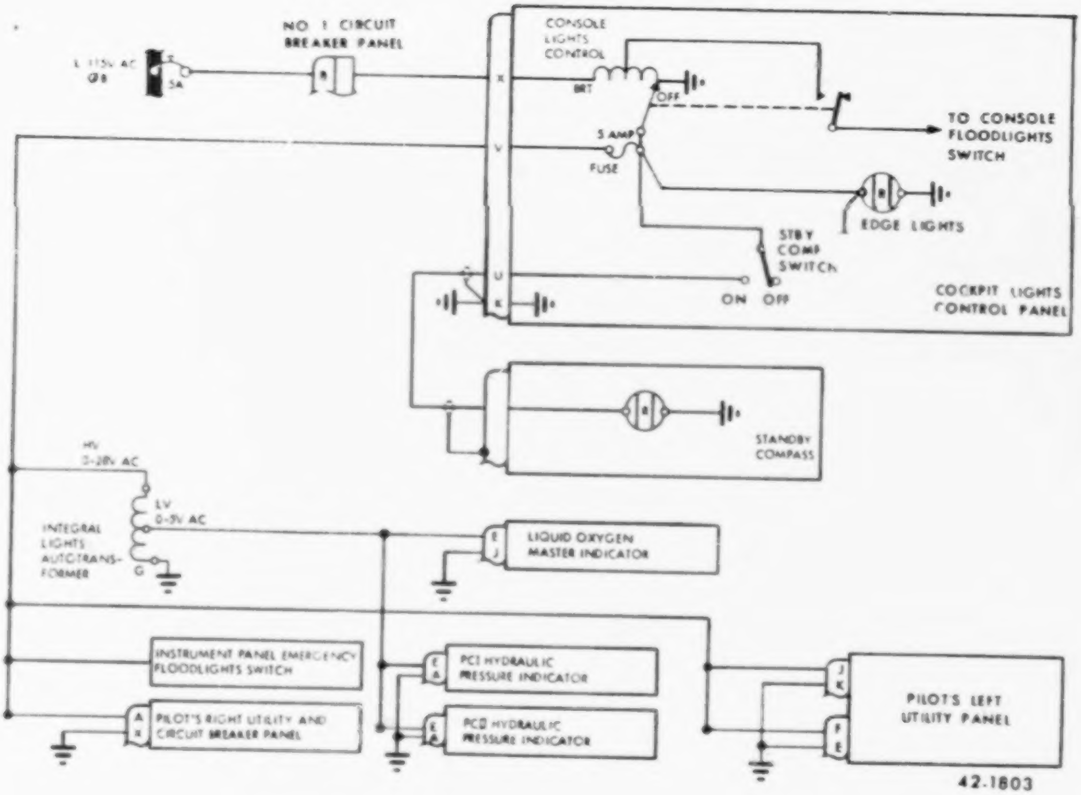

NO. 1 CIRCUIT BREAKER PANEL
L 115V AC ØB
5A
X
V
U
K
CONSOLE LIGHTS CONTROL
BRT
OFF
5 AMP FUSE
TO CONSOLE FLOODLIGHTS SWITCH
EDGE LIGHTS
STBY COMP SWITCH
ON OFF
COCKPIT LIGHTS CONTROL PANEL
STANDBY COMPASS
HV 0-28V AC
LV 0-5V AC
INTEGRAL LIGHTS AUTOTRANSFORMER
G
LIQUID OXYGEN MASTER INDICATOR
E
J
INSTRUMENT PANEL EMERGENCY FLOODLIGHTS SWITCH
PC1 HYDRAULIC PRESSURE INDICATOR
PC2 HYDRAULIC PRESSURE INDICATOR
PILOT'S RIGHT UTILITY AND CIRCUIT BREAKER PANEL
A
B
PILOT'S LEFT UTILITY PANEL
J
K
F
E
42-1803

Figure 4-1. Panel lights.

14-volt bus, and when they are in the BRT position, they have 28 volts applied. The floodlights have red lenses to reduce night blindness.

White floodlights (not shown) are provided on most aircraft for use during thunderstorms to lessen the blinding effect of lightning flashes. They are also used in the daytime just as it is getting dark or light. These lights are often connected to the DC bus and serve as emergency instrument lighting if AC power fails.

A utility spotlight, commonly referred to as a C–4 light, is generally located at each crewmember's station on most aircraft. It is attached to a long, coiled, electric cord. It can be removed from its mounting bracket and attached to any convenient spot by means of a spring clip. The light can be changed from red to white by turning the lens housing. The light contains an integral ON-OFF SWITCH that includes an intensity control. A pushbutton is provided on the case near the control switch. This button provides full light intensity, regardless of the setting of the intensity control. This light may be used for utility purposes as well as for map reading.

Warning lights. The number of warning lights installed in an aircraft varies, depending on the number and complexity of its systems. Each warning light is studied as a part of its specific system. However, provision is usually made for testing the operation of the lights as a group. In most cases this is done by means of a momentary contact toggle switch. When the switch is held on, the warning lights will illuminate, and they will go off when the switch is released. Warning lights are used to indicate unsafe conditions, such as landing gear that is not locked, low fuel level or pressure, or possibly a bomb bay door that is not completely closed.

Other interior lights. So far in this chapter we have discussed the lighting systems found on most aircraft. The larger tanker, cargo, and bomber-type aircraft have several lighting systems that are not required on smaller aircraft. Cargo and passenger aircraft have cabin and cargo compartment lights, which, of course, are unnecessary on other aircraft. Bombers have bomb bay lights, crawlway lights, and walkway lights, as well as lights in equipment storage areas.

Tanker aircraft, such as the KC–135, have lights in the boom operator's compartment that are similar to the lights in the pilot's compartment. These include instrument and panel lights, floodlights, and a utility spotlight; all of these have been described earlier.

Wheel wells on some of the larger aircraft also contain lights to provide illumination, either in flight or on the ground, for the wheel well and surrounding areas. A control switch is generally found in

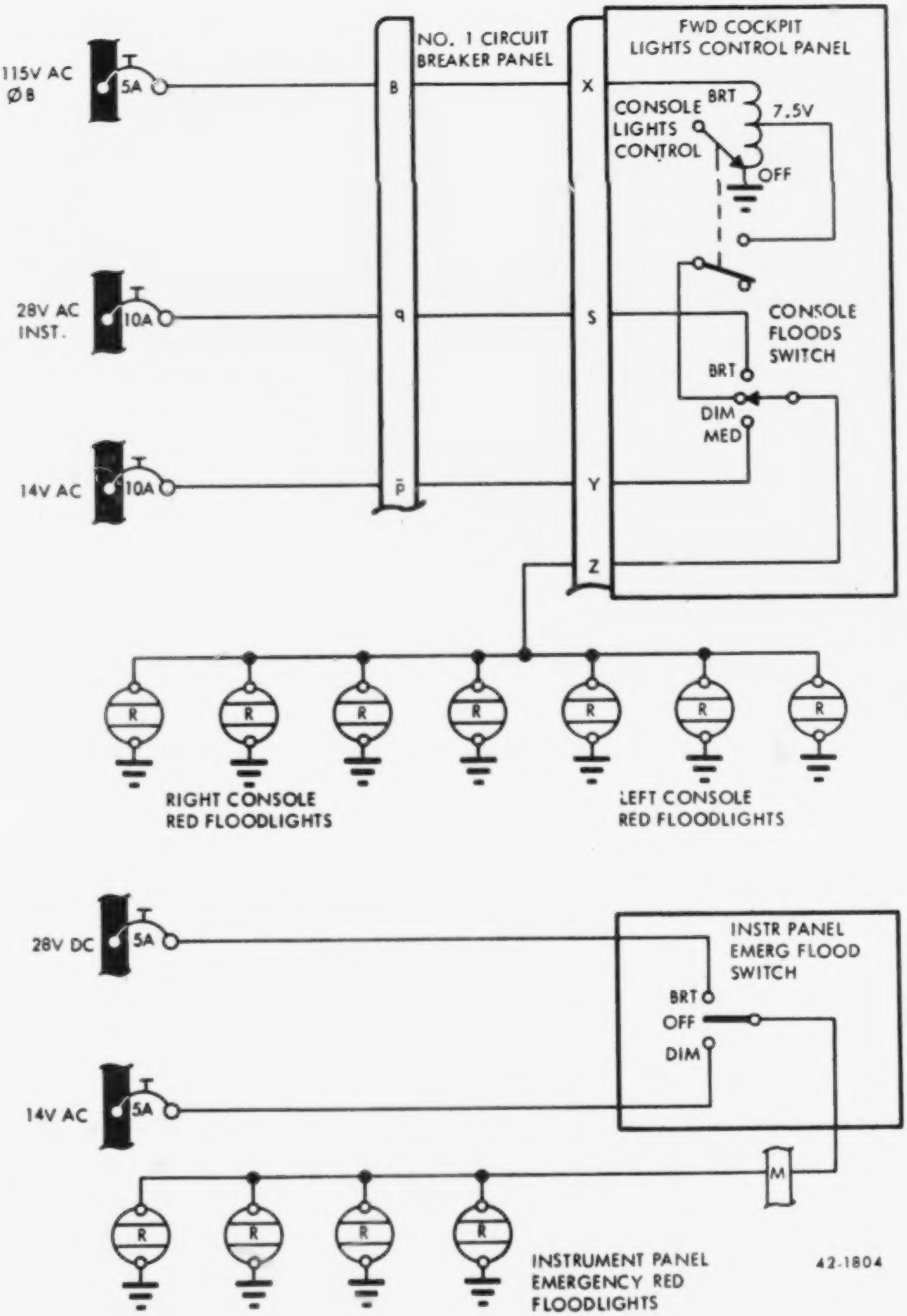

115V AC
ØB
5A
NO. 1 CIRCUIT
BREAKER PANEL
B
X
FWD COCKPIT
LIGHTS CONTROL PANEL
CONSOLE
LIGHTS
CONTROL
BRT
7.5V
OFF
28V AC
INST.
10A
q
S
CONSOLE
FLOODS
SWITCH
BRT
DIM
MED
14V AC
10A
p̄
Y
Z
R
RIGHT CONSOLE
RED FLOODLIGHTS
LEFT CONSOLE
RED FLOODLIGHTS
28V DC
5A
INSTR PANEL
EMERG FLOOD
SWITCH
BRT
OFF
DIM
14V AC
5A
M
INSTRUMENT PANEL
EMERGENCY RED
FLOODLIGHTS
42-1804

Figure 4-2. Floodlights.

one wheel well which the refueling crew can use to provide light for single point ground refueling. The wheel well lights may be operated on either AC or DC power. This situation enables the ground crew to operate the wheel well lights on DC power during ground refueling operations.

The trend in modern aircraft is toward AC lighting systems. Provisions are incorporated in these aircraft to provide DC power for emergency lights. Cabin lights, cargo compartment lights, and the ground refueling light are some of the lights that operate from this DC power.

Exercises (441):

1. Why does a bomber or cargo-type aircraft require more lighting systems than a fighter?

2. How are instruments illuminated if the primary instrument lighting fails?

3. Why do some cockpit instrument floodlights have red lens?

4. Why are the white instrument floodlights connected to the DC bus system?

5. How does pushing the pushbutton switch on the utility light affect its brilliancy?

6. What type lights would you likely find on cargo aircraft that would not be on fighter-type aircraft?

7. What special use is sometimes made of the wheel well lights on large aircraft?

442. Cite the purpose and operational characteristics of the exterior lights.

Operation of Exterior Lights. The exterior lighting systems generally fall into one of two categories: those that increase pilot visibility or those that attract the attention of other aircraft. The first category of improving visibility pertains to the landing and taxi light systems. These systems provide the lighting that is required on takeoffs, landings, and ground taxi operations. The second category of exterior lights, that of attracting attention, helps to prevent aircraft collisions. Systems that are designed to attract attention include navigation lights (often called position lights), anticollision lights, and join-up or formation lights. On aircraft that can be refueled in flight, lights are installed in the air refueling receptacle and at the wing roots for overwing lighting. Tanker-type aircraft also have additional exterior lights to facilitate refueling.

Landing lights. The landing light or lights are mounted so that when they are turned on they direct a beam of light forward. As their name implies, these lights are used for illumination during night landings. Landing light systems vary from one aircraft to another, but a typical circuit for an entire exterior lighting system is shown in figure 4-3. The control voltage for the landing light comes from the DC bus through a 5-ampere circuit breaker and the LANDING LT AND TAXI LIGHT SWITCH to the LANDING LIGHT RELAY. The relay ground is through the left main landing gear down limit switch. This insures that the landing light will not come on with the landing gear up. When the relay closes, 28-volt AC is applied to the landing light filament. In this particular installation, the landing light is installed in the door that covers the nose wheel well. When the wheel well door is open, the landing light is in proper position for landing.

As we mentioned earlier, landing light systems vary between aircraft. On some aircraft, a landing light is mounted in the leading edge of each wing, a light is attached to the nosewheel, or a retractable light is on the underside of the right wing. The two wing lights can be turned on and the retractable light can be extended and turned on with the landing gear up. The nose gear light will not come on until the gear is down and locked. DC is used to control the landing lights, including the motor of the retractable light; however, the filaments of all of them are energized by 28-volt AC. The retractable light is extended and retracted by a DC reversible motor. Limit switches are incorporated into the circuit to limit travel of the lamp assembly and to turn off the light when the assembly is retracted.

Another landing light system includes a crosswind landing light and a terrain clearance light. The crosswind landing light is mounted on the steerable front wheels and illuminates the area in the direction in which the front wheels are aimed rather than in the direction in which the aircraft is aimed. During the crosswind landing, the two directions may be quite different. The terrain clearance light is a retractable light that directs its light (when extended) down and forward so that the pilot may better judge his distance above the runway.

Another landing light system is a retractable-type assembly. This assembly carries a lamp that has two filaments of different wattage ratings. The high-

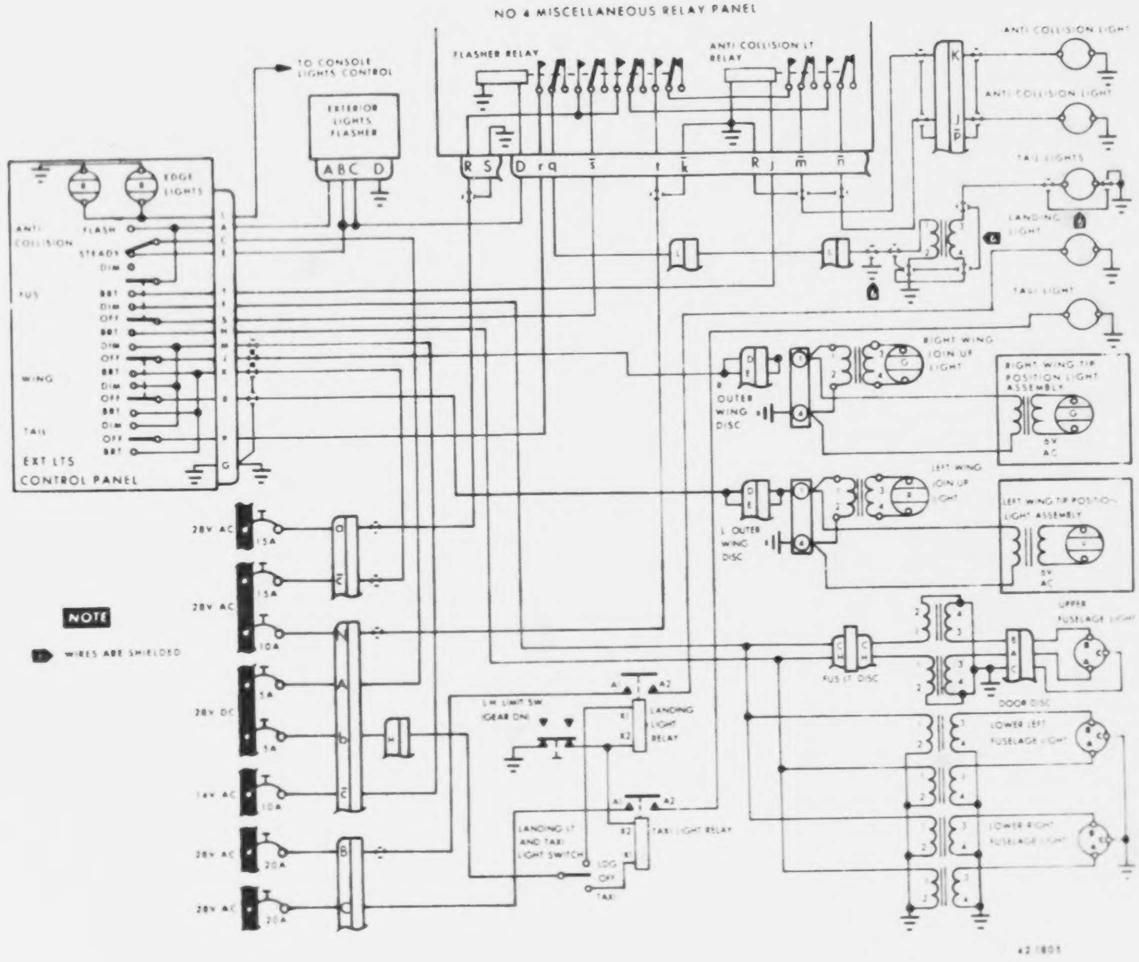

NO 4 MISCELLANEOUS RELAY PANEL
FLASHER RELAY
ANTI COLLISION LT RELAY
TO CONSOLE LIGHTS CONTROL
EXTERIOR LIGHTS FLASHER
EDGE LIGHTS
ANTI COLLISION
FLASH
STEADY
DIM
FUS
BRT
DIM
OFF
WING
TAIL
EXT LTS
CONTROL PANEL
ANTI COLLISION LIGHT
ANTI COLLISION LIGHT
TAIL LIGHTS
LANDING LIGHT
TAXI LIGHT
RIGHT WING JOIN UP LIGHT
R OUTER WING DISC
RIGHT WING TIP POSITION LIGHT ASSEMBLY
6V AC
LEFT WING JOIN UP LIGHT
L OUTER WING DISC
LEFT WING TIP POSITION LIGHT ASSEMBLY
6V AC
UPPER FUSELAGE LIGHT
FUS LT DISC
DOOR DISC
LOWER LEFT FUSELAGE LIGHT
LOWER RIGHT FUSELAGE LIGHT
28V AC
15A
28V AC
15A
10A
28V DC
5A
5A
14V AC
10A
28V AC
20A
28V AC
20A
NOTE
WIRES ARE SHIELDED
L.H. LIMIT SW (GEAR ON)
LANDING LIGHT RELAY
LANDING LT AND TAXI LIGHT SWITCH
LDG
OFF
TAXI
TAXI LIGHT RELAY
42 1801

Figure 4-3. Exterior lighting schematic.

wattage filament is in use when the control switch is in the LANDING LIGHT position, and the low-wattage filament has power applied when the switch is moved through OFF to the TAXI position.

Taxi lights. Taxi lights are used on aircraft to provide light while the aircraft is being taxied at night. They are usually not as bright as the landing lights, as indicated in the above paragraph, and are usually mounted in almost the same position. The taxi light system shown in the exterior light schematic (fig. 4-3) uses a separate terminal of the same control switch as the landing light and parallels the landing light circuit throughout.

On systems that employ the crosswind landing light, a crosswind taxi light is also mounted on the same bracket. This provides light ahead of the wheels when they are not pointing in the same direction as the aircraft because of a high crosswind.

In a typical tanker aircraft system, the wing illumination lights are incorporated into the taxi light system. The taxi and wing illumination lights may be turned on in flight to provide light during air refueling operations.

Position lights. The position lights are often called navigation lights. These lights are mounted on the wingtips and tail assembly of the aircraft. The left-wing light is red, the right-wing light is green, and the taillight is white. On the schematic of exterior lighting systems (fig. 4-3), it can be seen that the position lights are closely associated with the join-up lights. The join-up lights take the place of formation lights on some other types of aircraft. On the external lights control panel there are two switches that control the position lights. One of them controls both wing lights and the other controls the taillight. The lights may be placed in the DIM or BRT position.

Power for the lights when they are on BRT comes from a 28-volt AC bus through a 15-ampere circuit breaker. Power for the DIM lights comes from the 14-volt AC bus through a 10-ampere circuit breaker. Power for the wing lights then goes from the switch directly to the light transformers, where the voltage is stepped down to 6 volts for both the position lights and the join-up lights. Power for the white taillight goes to a set of contacts in the FLASHER RELAY and then to the taillight transformer. Notice the flags numbered "6" at the transformer and at the light. These flags indicate a note at the bottom of figure 4-3 which tells us of a change in wiring on some installations.

In order for the taillight to come on, the set of contacts in its power lead, controlled by the flasher relay, must be closed. In this way, this light is tied in with the flasher system and the anticollision system. Power to close to the FLASHER RELAY comes through the ANTICOLLISION SWITCH. When the switch is in the STEADY position, the FLASHER RELAY stays closed. When the switch is in the FLASH position, current to the FLASHER RELAY is interrupted by the flasher as it opens and closes the circuit. In the STEADY position, 28-volt DC is applied across the switch, across the jumper between B and C terminals of the flasher, and on the coil of the FLASHER RELAY. The taillight will now illuminate and remain as a steady white light.

When the ANTICOLLISION SWITCH is in the FLASH position, DC is applied to the A terminal of the flasher, causing the flasher to operate. The flasher consists of a DC motor that drives a rotary cam. This opens and closes a set of contacts and energizes terminals B and C at intervals. The interrupted power is then applied to the FLASHER RELAY, which opens and closes, causing the taillight to flash on and off. The flasher also controls the ANTICOLLISION LIGHTS.

Anticollision lights. The ANTICOLLISION LIGHTS are designed to flash on and off to attract the attention of other nearby aircraft so that collisions may be prevented. In our schematic circuit, the ANTICOLLISION LIGHTS and FUSELAGE LIGHTS are interconnected. Power for one (upper one on figure 4-3) of the ANTICOLLISION LIGHTS comes through a 10-ampere circuit breaker from the 28-volt AC bus. If passes through a set of contacts of the FLASHER RELAYS and the ANTICOLLISION RELAY before going to the light. Therefore, both relays must be energized before this light will illuminate.

Current for the other ANTICOLLISION LIGHT comes from the 28-volt AC line through a 15-ampere circuit breaker. This circuit breaker is larger than the circuit breaker that serves the other anticollision light, because power for the fuselage lights also comes through it. Current for this ANTICOLLISION LIGHT also passes through contacts in both relays and then on to the lights. At the FLASHER RELAY, a lead joins the anticollision power lead. This lead connects to a set of flasher relay contacts, which, when closed, will permit current to go to the fuselage light switch. From the switch it goes to the fuselage lights in either the DIM or BRT position. When it is in the BRT position, the flasher will be energized by the jumper across B and C terminals. However, the ANTICOLLISION RELAY will not be enrgized; therefore, the anticollision lights will not come on.

When we move the ANTICOLLISION SWITCH to the FLASH position, current from the flash terminal of the switch is applied to the top section of the FUSELAGE SWITCH. Now, if the FUSELAGE SWITCH is in the BRT position the ANTICOLLISION RELAY will close and the ANTICOLLISION LIGHTS will flash. To sum up, the ANTICOLLISION LIGHTS will come on only when the fuselage lights are on bright and flashing.

Another type of anticollision light has two bulbs that rotate in a housing. The motor will be either AC or DC, depending on the aircraft it is used on. This type of light, or rotating beacon as they are also called, is usually controlled by a single on/off switch.

Fuselage lights. The fuselage lights shown on our schematic of exterior lighting systems (fig. 4-3) are not found on all types of aircraft. The circuit for these lights is fairly simple. The switch setting determines whether the lights are bright or dim. They can be made to flash or burn steady at either switch setting. The lamps are of the double-filament type, and the filaments are of different wattage ratings. One of the filaments is energized for bright lights, the other for dim lights. A separate transformer that steps the voltage down to 6 volts from 28 volts is used to energize each filament.

Other exterior lighting circuits. Nearly every type of aircraft has some type of lighting circuit that is peculiar to its configuration, because it is designed to serve a particular purpose. For example, the join-up lights on the F–4C mark the trailing edge of the wingtip as a guide to other aircraft flying formation. Aircraft designed for air refueling have exterior lights marking the refueling receptacle.

Tanker aircraft are equipped with a rendezvous light system. This system consists of rotating lights on both the bottom and top of the aircraft. They serve as beacons for aircraft approaching for air refueling. Each lamp assembly contains four lights. Two of them reflect a high beam and the other two reflect a low beam. Also, two of the lights are of one color, and the others are another color. By controlling which color and which beam is illuminated, coded signals can be flashed to aircraft in the vicinity.

Exercises (442):

1. How do the landing and taxi lights differ in overall purpose from such lighting systems as the formation lights and position lights?

2. What feature in the nosegear landing light circuit in most aircraft prevents the landing light from being turned on accidentally?

3. In order to have an effective crosswind landing light, what must be true of the front wheels?

4. How are the wing taxi lights of some tanker planes used other than for taxi operations?

5. Give the colors and locations of the navigational wingtip lights.

6. Why are some lights switched from a bus that provides 28 volt AC to a bus that has only 14 volt AC applied to it?

7. What provision is made for opening and closing the flasher contacts?

8. Why are ANTICOLLISION LIGHTS designed to flash whenever they are used?

9. In the fuselage light system discussed in this chapter, explain what happens to the bulb filaments when the lights are switched from BRIGHT to DIM?

10. How does a tanker-type aircraft produce a coded signal for aircraft attempting a rendezvous for air refueling?

443. Identify what to look for when inspecting and troubleshooting the lighting system.

Inspection of the Lighting Systems. As in any system, when the system is inspected, workcards for that particular inspection are provided. One of the main things that will be inspected in the lighting system is in the operation of the lights, both interior and exterior, plus the operation of the DIM/BRT switch and the flasher. All wiring will be inspected for signs of chaffing, wire bundles for grommets when they pass through bulkheads, connector plugs for tightness and safety-wire where required, and tightness of nuts on terminal lugs on terminal blocks.

Troubleshooting the Lighting Systems. A great part of troubleshooting can be eliminated or at least reduced by carefully analyzing a malfunctioning system from technical order schematic diagrams. In most cases involving lighting systems, however, the trouble is a burned-out bulb. This trouble is so common that provisions are made to carry spare bulbs for the light installations that are accessible during flight. It is common practice to change the light bulb before performing any maintenance procedure, except checking to see that the circuit breaker has not opened. It is when changing bulbs does not correct a malfunction that circuit analysis and troubleshooting begins.

In order to analyze circuits, you must know the types of circuits, such as whether a circuit is a series, a parallel, or a combination series-parallel circuit. You must recognize the symbols used on schematic and wiring diagrams to denote circuit components.

Let us use the exterior light system schematic (see fig. 4-3) and determine from the diagram what the trouble might be if the taxi light did not come on but, with the switch in the proper position, the landing light lit. We stated above that changing the bulb would often be the first step when trouble developed, but in the case of a large light assembly, such as the taxi light, you would check it first. To determine the possible reasons for the lamp not burning, you should apply a little logic. We know the control circuit is good from the bus to the swtich because that much of the circuit is in common with the landing light. Also, the ground circuit of the relays is good through the L.H. LIMIT SWITCH (GEAR DN). So now the lead from the taxi terminal on the switch to the taxi relay coil, the relay coil, or the lead from X2 of the TAXI LIGHT RELAY to X2 of the LANDING LIGHT RELAY might be the trouble. Also, the trouble might be anywhere in the power circuit from the circuit breaker to the ground of the taxi light.

If the circuit analysis has been thorough, troubleshooting of the circuit consists of a few simple checks. The checks can be made with either a voltmeter or an ohmmeter. Most mechanics prefer the voltmeter because it is easier to use and is faster, and also because it is not necessary to isolate the circuit to get true readings when it is used. Since the circuit being tested with a voltmeter must have voltage applied when tests are being made, you must take necessary safety precautions.

Using the circuit of the taxi light that we analyzed on figure 4-3, a voltmeter check at terminal A2 of the relay would show if the relay closed properly. When the relay closed, a voltage would be found between A2 and ground. You must know and remember the voltage is AC at this point. The next checkpoint would usually be the lamp terminals to ground. Source voltage should be present at the input terminal and there should be no voltage at the ground terminal. If these readings are found but the light does not burn, the bulb is burned out. If voltage is found on the ground side, the ground lead is loose or broken. If zero voltage is found on the input terminal, an open in the lead going back to the relay is indicated.

When testing the same circuit with an ohmmeter, you should first open the circuit breaker of the control circuit, and then open the circuit breaker that carries power to the taxi relay contacts. A check with the ohmmeter from the terminal of the switch(marked TAXI on the schematic drawing) to ground should show the resistance of the relay coil. A check from A1 of the relay to the circuit terminal of the circuit breaker should show zero resistance. A check from A2 of the relay to ground would show continuity with the low cold resistance of the taxi bulb. If no continuity is found, check from the input side of the bulb to ground. At this point, continuity indicates an open lead back to the switch. If the meter needle does not deflect, check the ground side of the bulb to ground. A zero reading at that point shows an open bulb; no needle movement or a high reading indicates a broken or loose connection. After the trouble is found and corrected, the circuit is restored to an operating condition (circuit breaker closed) and the circuit tested for operation.

The time needed to analyze, troubleshoot, and repair the lighting circuit will depend on many things. The skill and experience of the crew that you have available will make a difference in the time involved. The type of aircraft and the circuits that are malfunctioning also will influence the time required for maintenance. It takes longer to replace a component, such as a flasher unit that won't operate, than it does to replace a light bulb or a faulty circuit breaker.

Other circuits of the schematic may be analyzed in much the same way. However, since some of the circuits contain more components and are more complicated than this one, in actual practice it would take more time to analyze them. After you have analyzed the sytem and have determined just what factors could cause a circuit to malfunction in a particular way, you are ready to troubleshoot.

Exercises (443):

1. When properly used, what helps to reduce troubleshooting time?

2. When checking a circuit with an ohmmeter, why must the section being checked be isolated from the rest of the circuit?

3. When inspecting the wiring, what do you look for?

4. If zero voltage is found on the input terminal of the taxi light circuit, what does this indicate?

444. Point out the procedures used when maintaining the lighting systems.

Maintaining the Lighting Systems. Many times pilots and crew members change light bulbs, using the spares that are stored in various locations throughout the aircraft. This is true only for the easily accessible lights, so in many cases you will be replacing more bulbs on exterior lights than interior. But what about other maintenance that is to be performed? There are components that must be installed, bench checked, repaired, overhauled, and modified. Granted, most of your maintenance in the lighting system will be devoted to changing bulbs, however, there are other maintenance functions that you will be required to perform. We will take a look at a few of them.

Installing components. Some of the components that you will be installing, other than bulbs, will be flasher units, landing light assemblies, and taxi light assemblies. The flasher unit is mounted using proper mounting hardware as outlined in the TO for your particular installation. Never use screws that are too long or too short. Make sure that the connector plug is secure, and last but not least, perform an operational check after you have completed the installation.

When installing landing and taxi light assemblies, special care and precautions must be taken so that power is not turned on while you are performing the installation. Many landing and taxi lights require adjustment after they are installed, while others must be adjusted in the shop. In either case, always check the applicable TO for correct procedures.

No matter whether you replace a bulb or major component, an operational check of that system must be performed.

Bench checking and repairing of components. Normally, the only lighting system components that are repaired and bench checked are the land/taxi lights and the rotating beacons. We will only discuss the rotating beacon.

When this component is brought into the shop, you must first disassemble it. This procedure is explained in detail in the overhaul and illustrated parts breakdown (IPB) TO. After it is disassembled, you must clean it with an approved cleaning solvent and check it over for defects to be repaired. Check all gears for cracks, chips, broken teeth, or excessive or uneven wear. Replace any gears that appear to be defective. If the electrical points are pitted or burned, you must replace them, also. The part numbers for the replacement parts are located in the IPB section of the TO. An example for the contacts would be A7629A. This would cross-reference to a National Stock Number and the correct part could then be ordered and installed.

Just about every part in the assembly can be replaced to repair the complete lamp assembly. Even if the connector on the assembly has damaged threads, it can be replaced. On this item, some minor soldering will be involved in order the replace the connector.

Gears, contacts, connectors, motors, and other miscellaneous parts, all of which are replaceable, can be utilized to make the rotating beacon serviceable.

Bench check the rotating mechanism prior to installing it into the base assembly in the following manner. Connect it to a variable input that ranges from 8 to 32 volts DC. Start at 8 volts DC and increase it 2 volts at a time. When you reach 28 volts DC, the gear will be checked using a stroboscope. At 28 volts DC, the speed should be 45 ± 5 rpm. Install the lamps and check it again at 28 volts. The gears will engage and operate without excessive noise, provided you lubricated them properly. The lamps must light without evidence of flickering or dimming. When these conditions are met, the assembly is considered serviceable. Complete the assembly by placing the red lens cover over the base and secure it with the retainer band and screw.

Overhaul and modifying components. Modification or overhaul on an electrical component in the lighting system is extremely limited due to the fact that there are so few repairable components. Most of the components in the system are either switches, bulbs, relays, or light assemblies, and are not the type that can be changed. Should a modification become necessary in a flasher unit, a landing/taxi light assembly, or a rotating beacon assembly, it will be in the form of a TCTO. It will contain the necessary overhaul instructions and the TCTO kit will contain all component parts necessary to complete the modification. When the modification is complete, an operational check must be made to insure that it operates properly.

Exercises (444):

1. Other than inspecting and troubleshooting the lighting systems, what other maintenance is performed by the electrician?

2. What installations will you be making in the lighting systems other than bulbs?

3. When bench checking the rotating beacon mechanism assembly, what type of power source should it be connected to?

4. What is used to check the speed of the gears in the rotating beacon, and what speed should it be?

4-2 Nesa Glass Anti-Icing System

Window anti-icing and window defogging is made possible by using electrically heated windows. The type of windows used for this purpose are known as Nesa glass windows.

Aircraft are equipped with Nesa windows in designated areas to provide a means for deicing and window defogging. The Nesa windows installed on aircraft are basically all the same. The Nesa window is a shatterproof window constructed somewhat like a "sandwich," having an inner glass pane, a layer of vinyl plastic, the Nesa compound, and the outer pane. Two bus bars are bonded to the Nesa film on opposite edges of the outer pane. These are joined to two external connectors which come from the AC power supply. To control the heat applied to the window, a temperature-sensing element is imbedded in the vinyl layer of the "sandwich" and connected to a temperature control unit through the proper leads. The window is assembled by inserting the glass "sandwich" into a molded phenolic frame, which is fastened to the aircraft structure with screws and clips.

445. Cite the operating principles of the Nesa glass system and tell how it works.

Operation of the Nesa Glass System. There are basically two types of Nesa windows. One type is used for both anti-icing and defogging. The other is a defogging only type. Both types of windows are "sandwich" constructed.

The windows that provide both anti-icing and defogging have the conductive coating between the outer pane and the vinyl plastic. The defogging windows have the conductive coating between the inner pane and the vinyl plastic. The defogging windows have the conductive coating between the inner pane and the vinyl plastic.

The sensing elements embedded in the vinyl plastic layer of the anti-icing and defogging windows provide the necessary temperature regulating. This is done by the resistance variations of the sensing elements as a result of window temperature change. This resistance change is transmitted to the controller amplifier and controller bridge rack (fig. 4-4). The bridge circuit between the amplifier and sensing unit controls the heat of the window by controlling the electrical power to the window. The window heat will be applied when the sensing element resistance is between 330 and 342 ohms. A voltage of 6.3 volts is supplied to the sensing element by a transformer contained in the controller amplifier (fig. 4-4) to es-

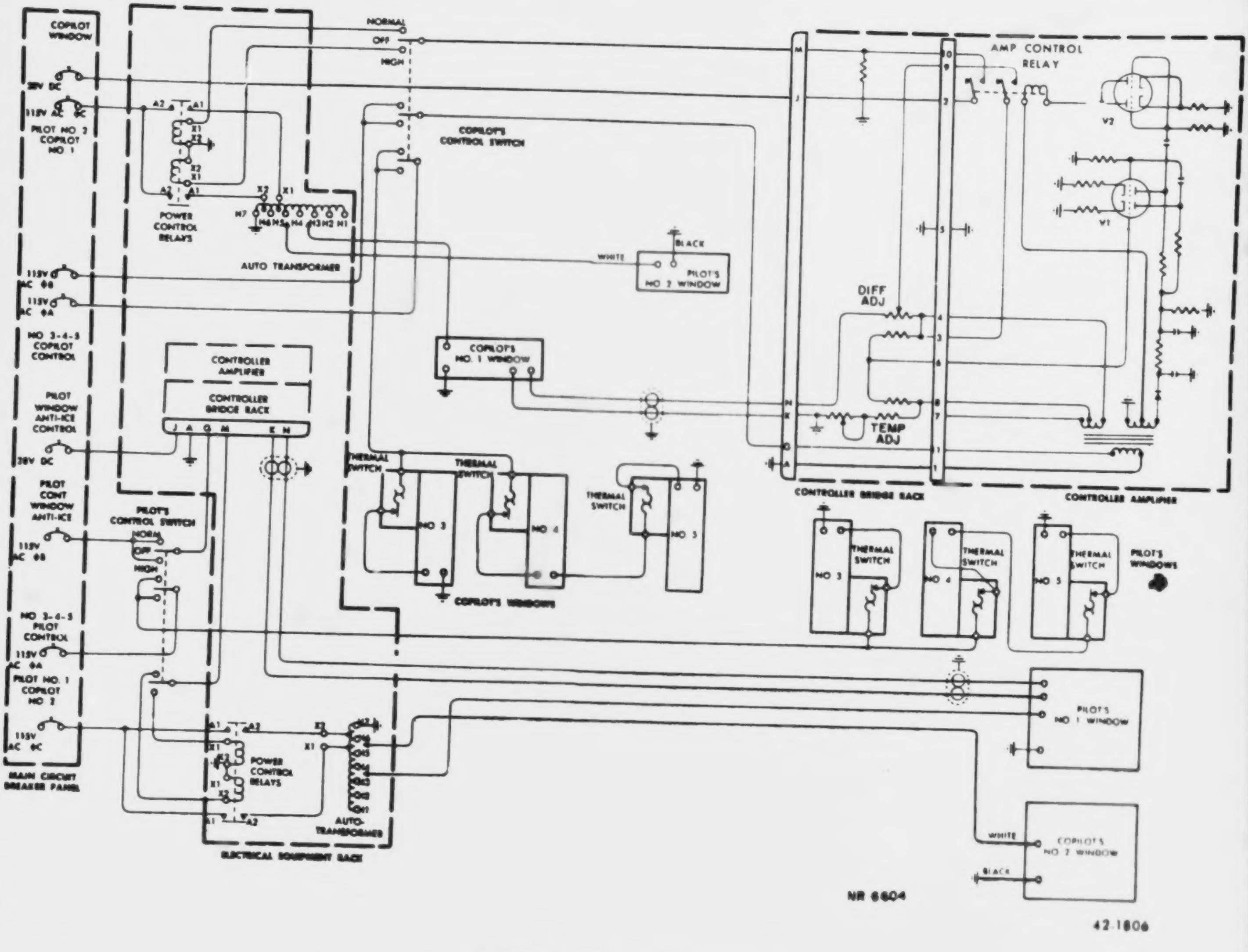

COPILOT WINDOW
28V DC
115V AC DC
PILOT NO. 2 COPILOT NO. 1
115V AC ΦB
115V AC ΦA
NO 3-4-5 COPILOT CONTROL
PILOT WINDOW ANTI-ICE CONTROL
28V DC
PILOT CONT WINDOW ANTI-ICE
115V AC ΦB
NO 3-4-5 PILOT CONTROL
115V AC ΦA
PILOT NO. 1 COPILOT NO 2
115V AC ΦC
MAIN CIRCUIT BREAKER PANEL
POWER CONTROL RELAYS
AUTO TRANSFORMER
NORMAL
OFF
HIGH
COPILOT'S CONTROL SWITCH
WHITE
BLACK
PILOT'S NO 2 WINDOW
COPILOT'S NO. 1 WINDOW
CONTROLLER AMPLIFIER
CONTROLLER BRIDGE RACK
J A G M K N
PILOT'S CONTROL SWITCH
NORM
OFF
HIGH
THERMAL SWITCH
NO 3
NO 4
NO 5
COPILOT'S WINDOWS
AMP CONTROL RELAY
V2
V1
DIFF ADJ
TEMP ADJ
CONTROLLER BRIDGE RACK
CONTROLLER AMPLIFIER
PILOT'S WINDOWS
PILOT'S NO 1 WINDOW
POWER CONTROL RELAYS
AUTO-TRANSFORMER
ELECTRICAL EQUIPMENT RACK
COPILOT'S NO 2 WINDOW
NR 6604
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Figure 4-4. Window anti-icing circuit.

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tablish the automatic temperature control point. Manual adjustments for the regulation of temperature between 32.3° C., (90° F.) and 54.5° C., (130° F.) are located on the exterior of the controller bridge. There are two adjustments that may be made on the controller amplifier. One of these adjustments may be made through the TEMPERATURE adjustment potentiometer, which is used to adjust the control point of the temperature desired. The other adjustment is through the DIFFERENTIAL adjustment potentiometer which is used to adjust the width of the temperature range and to provide positive closure of the relay contacts of the amplifier (fig. 4-4). This is the only maintenance that you can perform on the amplifier while it is installed on the aircraft, so if these two adjustments do not correct the trouble, replace the unit.

In some cases the Nesa window's electrical resistance will increase with age. It is possible to have an overheat condition occur in a No. 2 window if a resistance increase should take place in the mating No. 1 window.

The temperature control circuit for the defog windows is somewhat different from that previously discussed for the anti-icing windows. The temperature for these windows is controlled by individual thermal snap switches.

The thermal switch face is held in contact with the inner pane by means of a torsion spring on the switch bracket. A marked arrow is provided on the window edge to enable the thermal switch to be placed in the proper position. The switch is an SPST switch rated at 115 volts AC at 380 to 1000 hertz. The contacts are normally closed and have a control point of approximately 100° F.

The thermal snap switches for the defog windows are connected to a 115-volt AC source and provide a window heating voltage of approximately 7 volts AC to the No. 4 windows (fig. 4-4) and 45 volts AC to the No. 5 windows. The No. 3 windows are in parallel with the 4 and 5 combinations, as shown in figure 4-4.

The electrical system uses 28 volts DC and 115 volts AC. The 28-volt DC circuit (see fig. 4-4) merely supplies power to close an AC power relay. You will note in figure 4-4 that the AC relay, when closed, completes a circuit to the autotransformer; the 115 volts AC to this transformer is stepped up to approximately 250 volts AC in the LOW selection of power. This increased voltage applied directly to the Nesa window causes it to heat. In the high switch position, the voltage from the transformer is approximately 400 volts. The window temperature range itself is not affected by either type of voltage applied; the higher voltage merely allows the window to reach the proper temperature sooner.

Perhaps, at this point, we should caution you about selecting the voltage that you apply to the window. You should always place the control switch, which is a gang-type switch, in the low position and allow a 15-minute warmup period before moving it to the HIGH position. You can easily see that initially selecting the HIGH position without allowing the 15-minute warmup period might bring on real trouble. A rapid application of heat to a cold window surface might easily break the glass. After the warmup period, you can move the switch to the HIGH position. The HIGH switch position is needed only during extreme icing conditions. You will find that for purposes of normal operation the switch can stay in the low position.

The anti-icing windows contain sensing elements. The resistance of this element is the fourth leg of a Wheatstone bridge. When the element is cold, its resistance is such that the bridge circuit becomes unbalanced. When this happens, a signal appears at the amplifier, where it is amplified and sent on to energize the amplifier control relay. You will notice by tracing through the circuit that when the amplifier control relay closes, the DC circuit is completed to the AC power relay, which allows AC to be applied to the window. When power is applied to the window, the temperature-sensing element embedded in the window begins to absorb heat from the warming Nesa compound and starts to change its resistance. When the temperature of the glass surface reaches the desired setting, the resistance of the sensing element is such that the bridge circuit is balanced. This cancels the signal to the amplifier and shuts off the heat. When the window cools to a point at which the bridge circuit again becomes unbalanced, the cycle is repeated. Perhaps you are wondering what the temperature of the Nesa glass is under operating conditions. Usually the sensing element unbalances the bridge circuit when the temperature drops below 100° F. (37.7° C.).

For a satisfactory operational check, the ambient temperature should not be above 75° F. All the window leads should be connected to the proper transformer terminals (see table 4-1). When the sensing leads from the pilot's window No. 1 and the power leads from pilot's No. 1 and copilot's No. 2 windows are disconnected, a 0- to 500-voltage voltemeter is placed across the power leads of window No. 1 and a similar voltmeter is placed across the power leads of window No. 2. A 0- to 400-ohm resistance box, set at 342 ohms, is placed across the sensing leads. With external power connected and the window heat control switch moved to the NORMAL position, the voltmeter should read zero. Resistance of both windows is measured with power off. If the resistances are within the ranges corresponding to the values shown in table 4-1, the windows are satifactory. A resistance check of the sensing element should be made if no voltage appears or if the controller does not operate to reduce the voltage to zero within 2 minutes with an ambient temperature of 70° F. or greater. If the controller works satisfactorily and the window heat control switch is placed in the HIGH position, the voltage should read in accordance with column 5 of table 4-1 when the controller power cycle is on. It is important that the windows are not damaged due to overheat. The thermal switch

TABLE 4-1
NESA WINDOW TROUBLESHOOTING TABLE

	Window Terminal Marking	Transformer Terminal Marking	Resistance in Ohms	Voltage (Approx) Window Heat Control Switch "Normal"	Voltage (Approx) Window Heat Control Switch "High"
PILOT or COPILOT No. 1 Window	H1	H1	43.8 - 48	218	304
	H2	H2	39.6 - 43.8	210	289
	H3	H3	35.4 - 39.6	198	275
	H11	H1	38.8 - 42.6	218	304
	H12	H2	35.1 - 38.8	210	289
	H13	H3	31.4 - 35.1	198	275
PILOT or COPILOT No. 2 Window	H4 H5 H6	H6	53.9 - 72.9	164	228
	H14	H4	69.0 - 75.5	181	251
	H15	H5	62.3 - 69.0	173	239
	H16	H6	55.7 - 62.3	164	228

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should operate to remove power from the window in approximately 10 minutes, if the temperature is 70° F. The applicable TO will give specifications of an operational check for a particular window.

Exercises (445):

1. Basically, what are the two types of Nesa windows?

2. What is the function of the controller amplifier in the Nesa anti-ice circuit?

3. What temperatures can be obtained through manual adjustment?

4. What is the purpose of the 28 volts DC in the circuit?

5. At what temperature will the Nesa glass unbalance the bridge?

6. What is the purpose of a thermal switch in the Nesa window anti-icing circuit?

446. Cite procedures relative to inspecting and troubleshooting the Nesa glass system.

Inspection of the Nesa Glass System. Inspection of the Nesa glass system is limited to checking the controller amplifier for security of mounting and condition of associated wiring. The individual window units can be checked for proper resistance. Inspection workcards are used on all scheduled inspections. The condition of the wiring should not be overlooked. When you inspect the wiring, look for signs of chaffing, binding, and deterioration. When checking the Nesa window itself, look for cracks, bubbles, and discoloration. If any of these conditions are found, the applicable technical order must be checked to determine if the condition is serious enough to warrant window replacement. A good inspection can save a lot of work later on when the aircraft is scheduled for flight, and then can't make it because of a malfunction. The main object of inspecting is to locate and repair a minor problem before it becomes a major defect.

Troubleshooting the Nesa Glass System.. When troubleshooting the window anti-icing circuits, you should be extra cautious. There are some very high

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voltages in this system that could be dangerous to both personnel and equipment.

Referring to figure 4-4, if Nos. 4 and 5 pilot's windows are inoperative and No. 3 window is operating satisfactory, the probable cause is a defective thermal switch or wire. A test of the thermal switch on No. 4 window should indicate continuity. If there is no continuity, the thermal switch is defective and should be replaced. There should be a continuity reading of the wiring from No. 4 switch through No. 5 switch. if there is no continuity, an open circuit exists and all defective wiring should be repaired or replaced.

Now let us suppose that the copilot's set of windows fails to heat with the control switch in any position. There are several things that could cause this trouble: the circuit breaker, the sensing element, the temperature controller, the autotransformer, or the control switch. The circuit breakers should be closed (pushed in) and serviceable. After disconnecting the leads to the sensing element at the window, a reading of continuity of the element should be present. If there is no continuity, the element is defective and must be replaced. Substituting a new controller amplifier and/or controller bridge rack for the original one will determine whether or not the original controller is defective. Disconnecting either the X_1 or the X_2 lead from the autotransformer and applying 115 volts Ac, 400-hertz power directly to the unit will determine the status of the autotransformer. High voltage will be present, and extreme caution must be observed. Refer again to table 4-1. This load voltage from H1 through H6 should agree with those given in table 4-1; if not, replace the defective autotransformer. The control switch should read continuity across the switch terminals of its respective NORMAL or HIGH position. If there is no continunity on either check, the switch must be replaced. There should be continuity of wiring between each component. If the resistance is infinite, then repair or replace all defective wiring.

Exercises (446):

1. What can be checked on the individual window units in the Nesa glass system?

2. a. Referring to table 4-1, what should be the resistance of the window unit with terminal markings H11?

   b. What is the normal heating voltage?

   c. What is the high heating voltage?

3. How can you determine if a Nesa window should be replaced?

447. Cite the maintenance that is normally performed on the Nesa anti-icing system.

Maintaining the Nesa Glass System. The Nesa glass system is a relatively easy system to maintain. There are few components in the system and they are not difficult to locate. You will have to install a component occasionally, bench check some components, repair the malfunction in them, and now and then you may have to perform a modification on a component or overhaul one. The repair and overhaul phase are closely related. We will mention each of these in the remainder of the chapter.

Installing components. About the only components you will be installing in this system are the controller bridge rack, the controller amplifier, power control relays, autotransformers, and thermal switches. Occasionally, a circuit breaker or switch may have to be installed when the one in the system becomes defective. Two other things you may have to do is install thermal switches and connect the wiring after a defective Nesa glass is removed and replaced. The tech order must be followed when connecting any wiring after component installation to prevent damaging that component or the rest of the system.

Bench check and repair of components. The majority of the bench testing and repair consists of testing the tubes in the control amplifier and replacing them. The thermal switches, relays, transformers, and windows are not repairable. This means that the only components you will repair are the controller amplifier and the controller bridge rack. The other tests you will be making on this system are voltage and resistance checks.

Overhauling and modifying components. When a certain component continues to fail over and over for the same reason, it indicates that a deficiency exists in the system. Generally the deficiency is in a component. a change, either minor or major, will most likely result. You may get this change in the form of a TCTO. This could direct you to make a slight change in the system or to begin utilizing a new component. The actual modification of the component could be done at depot-level during an overhaul of the component, or by you on the flight line. The TCTO kit contains the parts necessary to complete the modification.

Exercises (447):

1. What maintenance is normally performed on the anti-ice system other than inspection and troubleshooting?

2. Most changes to a system or component, because of a continual failure, are in the form of a __________.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 - 1. Place the gear control handle in either the UP or DN position.
2. a. Right main landing gear motor.
   b. Left main landing gear motor.
   c. Unlock side of the nose landing gear uplock cylinder.
   d. Nose landing gear actuating cylinder.
3. The uplock cylinder must release the landing gear.
4. The airplane must be in the air and the landing control handle must be in the UP position.

401 - 1. a. The landing gear is not down and locked and any throttle is retarded below minimum cruise power.
   b. The landing gear is not down and locked and the wing flaps are less than 75 percent extended.
2. a. This opens the warning light circuit. Extinguishes the warning light.
   b. When the landing gear is fully extended and locked.
3. a. To the other side of the horn silence relay.
   b. A lock-in circuit maintains a closed circuit for the silencer relay associated with the particular throttle that initiated the warning.
   c. Yes. The lock-in circuit maintains a closed circuit for the particular throttle that initiated the warning.

402 - 1. a. Signs of deterioration, binding, and security.
   b. Security of mounting and wiring.
2. The aircraft should be placed on jacks, and electrical and hydraulic power should be readily available.
3. Insure: (1) that there is a good firm connection at the LG control (on the DC bus), (2) that the circuit breaker was operating OK and had good connections, (3) that the wire to the landing gear control switch was not faulty, (4) that there is a good connection to the landing gear control switch, (5) that the landing gear control switch and its contacts are functioning properly.

403 - 1. a. Remove IAW the applicable TO.
   b. It would not be repaired at base or depot. It's a base expendable item.
   c. The new item should be replaced IAW the applicable TO.
   d. Perform an operational check IAW the applicable TO.
2. a. The Air Force System Command (AFSC).
   b. A time compliance technical order (TCTO).
   c. In a kit that is included with the TCTO.
   d. Perform an operational check IAW the applicable TO.

404 - 1. Three-way solenoid operated valves.
2. a. "L," "X," and "Z" relays.
   b. "Y" and "V" relays.
3. The main 28-volt DC bus.
4. The "X" relay after 0.7 second.
5. Fail-safe feature with a 3.5-second delay.
6. The "Z" relay.

405 - 1. Security of connector plugs and safety wire installed on those where it is required.
2. Inspection workcards.
3. Only current technical data.
4. The operational check of the system.

406 - 1. A substitute as long as it has the same specifications.
2. Repair to the antiskid system is generally limited to the removal and replacement of defective components.
3. A locally manufactured tester.

407 - 1. a. The auxiliary air door relay.
   b. By moving the landing gear control handle to the UP position.
   c. In the DN position.
2. Command potentiometer, followup potentiometer, automatic checking differential amplifiers, and the center tap of the servo valve connector.
3. 140°.
4. It is energized.
5. The nose gear up relay.

408 - 1. a. The rudder pedals.
   b. The nose gear steering command potentiometer.
   c. The differential amplifier. In the nose gear steering control box.
   d. In the nose gear steering servo valve.
2. a. The followup potentiometer.
   b. To the differential amplifier.
   c. An error signal.
   d. The followup and the command potentiometer.
   e. A differential current.
   f. The servo valve directs hydraulic fluid to flow to the vane motor in the nose gear steering power unit and the vane motor turns the nose wheels in the desired direction.
   g. It is reduced to zero.

409 - 1. a. The potentiometer.
   b. Erratic operation of nose gear steering.
2. a. 100 mv.
   b. The control box is OK.
3. a. A torque collar rotation rate of 3.4 to 4 rpm.
   b. 15 to 17.6 seconds per revolution.
   c. If any spikes are above 100 mv.
4. Indications on b and d are not acceptable indications.

410 - 1. a. The TO used for repair or overhaul.
   b. To apply a liberal amount of silicone compound in the receptacle.
   c. To perform a detailed operational check IAW a specified TO paragraph.
2. An operational check.
3. With a test set to test the system on the flight line.
4. The AN/AJM-20.

CHAPTER 2

411 - 1. Disconnects the power actuators in the event of actuator jamming or binding.
2. Limit switches halt power to the drive unit.
3. Electrically controlled clutches.
4. It would result in excessive wear of the ball detent clutch, or stalling the motor.

5. Moving up.
6. 13 minutes.
7. The CUT-OUT position.

412 - 1. Upwards toward the switch body.
2. To a length of 12 inches.
3. Wires 1 and 4.
4. To prevent excessive hammering as each stop nut is actuated.

413 - 1. Stabilizer trim cutout switch.
2. Cutout.
3. Nose down limit switch.
4. Open ground.

414 - 1. Bench check it to determine serviceability.
2. To eliminate the actuator portion of the system.
3. It is usually a locally manufactured item.
4. A 7-minute cooling period.
5. It should be adjusted so that less than half of the travel is available for NOSE UP trim, and the remainder for NOSE DN trim.
6. Up.

415 - 1. Remember to be FOD conscious.
2. Before you remove the control wheel.
3. Inspect the wire bundle for serviceability.
4. No.
5. Before the control column is reinstalled.

416 - 1. The control stick grip trim switch.
2. Takeoff trim indicator lights.
3. A trim switch.
4. Trim actuators.

417 - 1. The control switch or motor limit switch.
2. They direct hydraulic flow and pressure to the ailerons.
3. No.
4. It will go out as soon as the switch is released.
5. Closed.
6. No.

418 - 1. The electric and hydraulic.
2. GROUND.
3. Up.

419 - 1. By increasing the lift effect.
2. Electrical control.
3. Slotted and Fowler.
4. It eliminates some undesirable stall characteristics.
5. It has the lower surface of the trailing edge rolling back on tracks.
6. They automatically reduce the stall characteristics.

420 - 1. In the form of kits.
2. No.
3. The applicable TO.
4. To adjust the limit switches.
5. All the aircraft could be grounded until the modification is completed.

421 - 1. Circuit breakers.
2. The horn.
3. Flap warning switch.
4. Leading-edge flap warning switch.

CHAPTER 3

422 - 1. From the aircraft's engine supply.
2. About 35 percent.
3. Centrifugal switches.
4. A compressor in the aircraft does it automatically.
5. At 40°F. To prevent freezing of moisture in the air moisture separator.

423 - 1. Two. Either a ground operated power unit or bleed air from the compressor of another engine.
2. The ground for the starter control valve is open and the starter will not operate.
3. It is vented overboard to prevent the starter from operating.
4. The starter valve solenoid.
5. To keep air pressure on the turbine wheel constant and to maintain the desired starter speed.

424 - 1. To provide protection against overpressure conditions.
2. To provide against overspeed conditions.
3. A sheared shaft, although a fast burning cartridge could cause overspeed, also.
4. During an overspeed condition, the pressure-relief squib is fired, which ruptures the pressure relief valve and vents the cartridge gas to the exhaust of the starter.
5. Since they can fire with as little as 0.5 amp, never use a standard multimeter to test them and keep the leads shorted together if you have to transport it. Always wear protective gloves and glasses when working with them.
6. No. The pressure-relief squib cannot be ignited during a low-pressure start since the selector switch is in the low-pressure position.

425 - 1. A high-ratio transformer, an inverter.
2. A vibrator, a transformer, igniter plugs.
3. 20,000 volts.
4. Changes 28 volts DC to pulsating current.

426 - 1. It is used to ignite the fuel and air mixture.
2. Two.
3. Blast away carbon deposits from the center electrode.
4. In the "A" model, the signal goes through the throttle switch; the signal goes through the start lever in the "B" model.
5. The compositor is built into the ignition unit on the "B" model.

427 - 1. Be sure the ignition and start switch is in the OFF position. Be sure the circuit breakers are pulled. Do not apply input power to the ignition unit unless the igniter plug is connected. Discharge the capacitor when working around the igniter plug.
2. An area free from fuel fumes.
3. Hold the applicable ignition and start switch in the GROUND START position.
4. Get some assistance from the engine shop.
5. Possibility of electrical shocks and burns.

428 - 1. To correct malfunctions before they occur.
2. Inspection workcards.
3. Analyze the problem.
4. To perform an operational check.

429 - 1. In applicable TOs.
2. None, they are returned to supply and repaired at the depot level.
3. A TCTO, approved by AFSC (Air Force Systems Command).

403 - 1. The data plate should indicate 115/200-volt, 400-hertz, three-phase, AC induction motor.
2. The motor-driven sliding-gate type.
3. The rotary plug type.

4. The fuel level control valve admits fuel into each tank and automatically shuts off the fuel flow when the tank is full.
5. Closed fuel control valve during refueling.
6. No fuel flow during engine fuel feeding.
7. Red indicator light.

431 - 1. Master switch ON and refuel valve control switch OPEN.
2. To determine that the pump discharge pressure at no-flow for the main tank and auxiliary tank boost pumps is within the permissible range.
3. To remove fuel trapped in the manifold by air refueling in flight or single-point refueling on the ground.
4. Scavenge pump, shutoff valve, float switch, control switch, and amber indicating lights.
5. Approximately 2 gallons per minute.
6. A float switch located in the scavenge drain line.

432 - 1. Inspection workcards.
2. An unsafe condition that could have caused the aircraft to miss a scheduled flight.
3. Each reading between phases should be within a maximum spread of 10 ohms of each other.

433 - 1. A wiring diagram.
2. A TCTO, approved by AFSC.
3. Depending on the urgency, it will be completed during an overhaul or a phased inspection, or the aircraft may be grounded until the modification is completed.

434 - 1. On conventional aircraft they are placed in the engine and baggage compartments, and the engine section, nacelle, or tail cone of jet type aircraft.
2. In parallel with each other and in series with the warning light.
3. It is a heat-sensitive unit that completes a circuit from ground through a warning light to the power source when the heat in the area of the detector rises above a certain value.
4. The inside of the switch has a low coefficient of expansion while the shell has a high coefficient of expansion. When they are heated, they will expand and contact will be made.
5. Never handle them with pliers or force them in position with tools or by hand, and avoid denting them before or after installation.
6. Yes. By maintenance personnel, to any desired temperature within the unit's range.

435 - 1. The rate of temperature rise.
2. The sensitive relay, the slave relay, and the thermal test unit.
3. In series.
4. When the temperature rises rapidly enough the thermocouples will produce a voltage. This causes current to flow in the circuit that energizes the sensitive relay, which in turn closes the slave relay and completes a circuit to the warning light.
5. By using the lowest amperage or voltage scale on a multimeter to check for proper polarity.
6. Because a reversed thermocouple will not only fail to operate the system, but it will have a tendency to counteract the output of other correctly connected thermocouples.

436 - 1. Between 7 and 60 hertz.
2. The overheat light flashes and the fire warning is steady.
3. A Fireye tester with an oscilloscope or a VTVM.
4. NORMAL.

437 - 1. A rise in ambient temperature causes the resistance between the center conductor and the outer conductor of the sensing loop to decrease. The resistance of the sensing loop is part of a bridge circuit; and once the bridge circuit becomes unbalanced due to a change in resistance, current will flow, causing the warning light to come on.
2. In series with each other.
3. With a megger.
4. (1) The system checkout; (2) the cable assembly checkout.

438 - 1. In parallel, so if one light bulb burns out, the other two are not affected.
2. It has approximately a 1-second delay.
3. When the variacs are rotated clockwise approximately 25° from the OFF position.
4. The master warning lamp will go out when the lamp assembly is pushed and will remain out until a different individual warning lamp signals trouble within its system, or automatically when the individual fault has been corrected.

439 - 1. The takeoff warning circuit indicates when the aircraft is ready for flight by monitoring relays, such as doors open, spoilers closed, thrust-reverser, flap position takeoff, and horizontal trim relay. A green light indicates that takeoff can be started.

440 - 1. It must have an operational check.
2. Replace it with a new one.
3. The TCTO is the authorization for a modification and the TCTO kit provides the parts.

CHAPTER 4

441 - 1. The amount of lighting required by aircraft is partially determined by the number of crewmembers and size. Since fighters are smaller and have fewer crewmembers, more lighting systems are needed on bomber and cargo aircraft.
2. If the primary instrument lights fail, floodlights illuminate the instruments.
3. To reduce night blindness.
4. Because they are the emergency lights and they can be used when AC power fails.
5. When the pushbutton on the utility light is pushed, the intensity control has no effect on the light, so it burns at its greatest brilliance.
6. Cargo aircraft have cabin and cargo compartment lights in addition to the cockpit lights found on fighter-type aircraft.
7. The wheel well lights, besides being used for illumination of the wheel well in flight, provide light for single-point refueling when the aircraft is on the ground.

442 - 1. Landing and taxi lights are designed to provide illumination on other objects. Position and formation lights are designed to attract attention or to be seen.
2. The landing gear must be down and locked before the light will come on.
3. The front wheels must be steerable.
4. To provide light during refueling operations.
5. Left wing light, red; right wing light, green.
6. To switch from BRIGHT to DIM.
7. A DC motor drives a rotary cam which opens and closes the flasher contacts.
8. The ANTICOLLISION LIGHTS are designed to flash in order to attract attention of the crew of any nearby aircraft and thereby help to prevent a collision.
9. The fuselage lights discussed in this chapter are dual filament bulbs. The higher wattage filament is energized for bright lights, while the lower wattage filament is energized for dim lights.

10. By controlling the color and also by controlling whether a high or low beam is shown from the rendezvous lights.

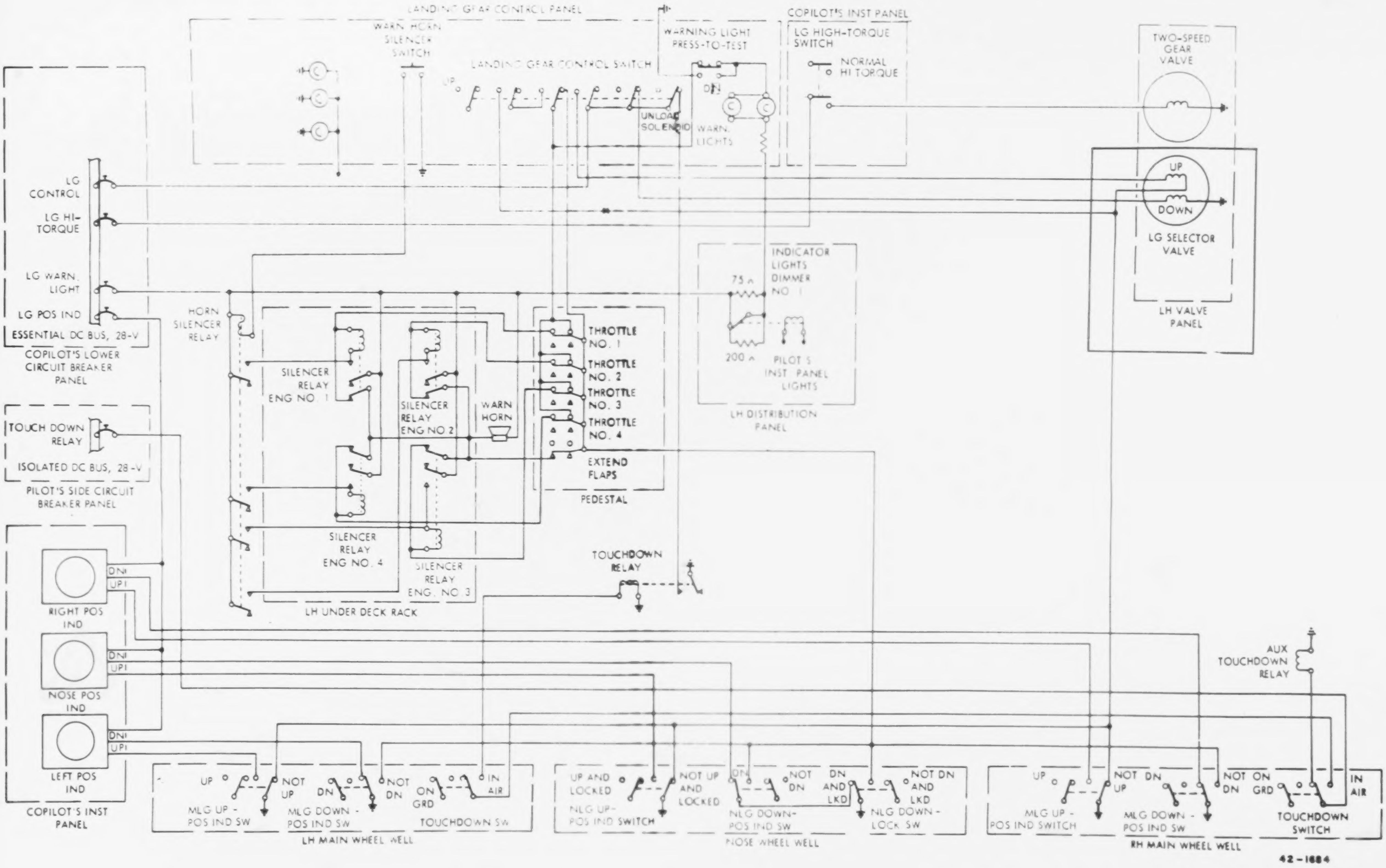
443 - 1. Technical order schematics.
2. Incorrect readings may result if the section of the circuit being checked is not isolated.
3. Signs of chaffing, grommets on wire bundles going through bulkheads, connector plugs for tightness and safety-wire where required, and security of nuts on the terminal lugs.
4. An open in the lead going back to the relay.

444 - 1. Install, bench check, repair, overhaul, and modify components.
2. Flasher units, landing light assemblies, and taxi light assemblies.
3. A variable power source that ranges from 8 to 32 volts DC.
4. A stroboscope. The speed should be 45 ± 5 rpm.

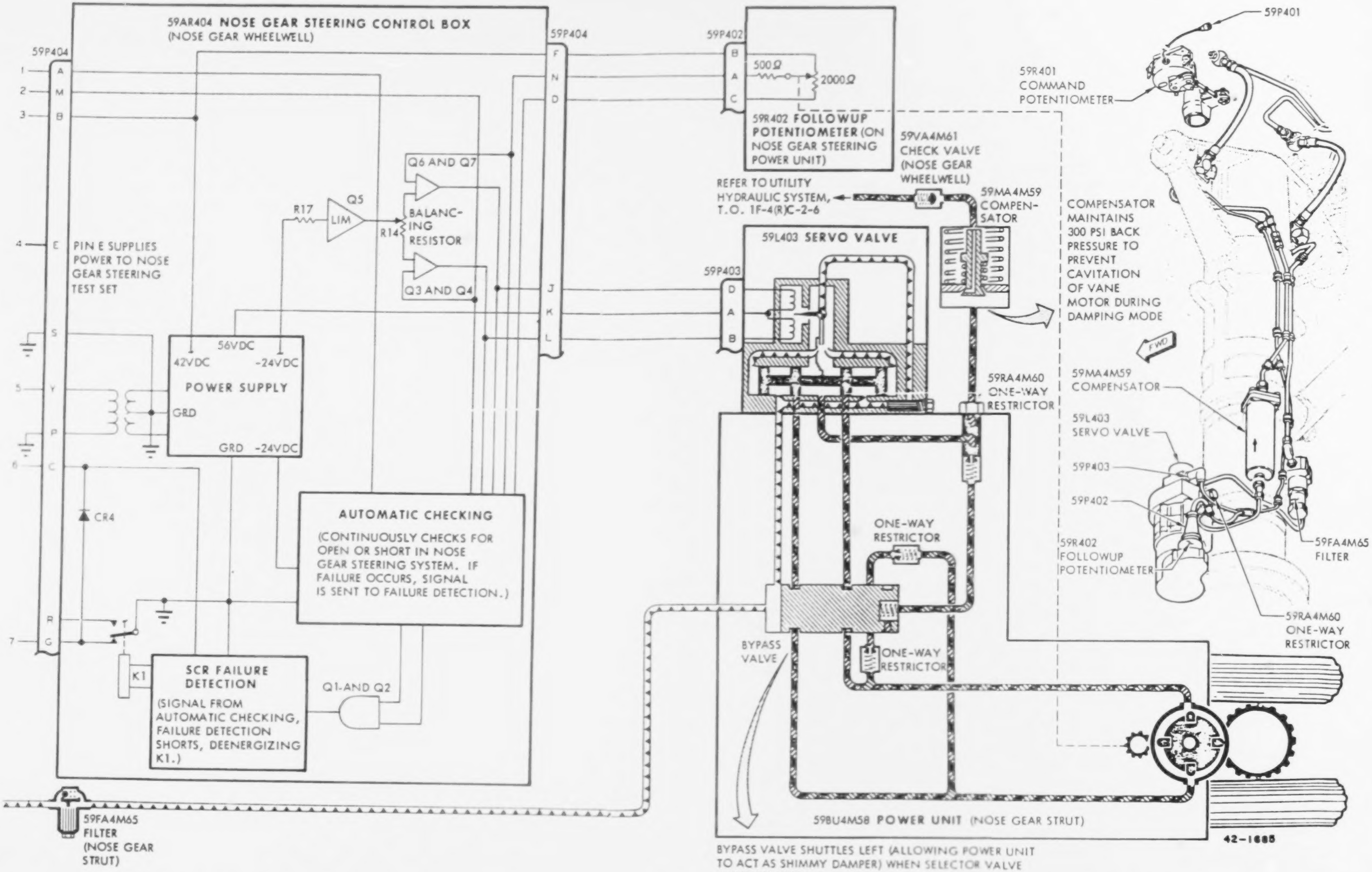
445 - 1. The anti-icing/defogging type and the defogging only type.
2. To control the heat of a window by means of a bridge circuit between the sensing element and the controller amplifier.
3. 32.3° C., (90° F.) to 54.5° C., (130° F.).
4. To supply power to close the AC power relay.
5. At temperatures below 100° F. (37.7° C.).
6. To remove power from the window after approximately 10 minutes if the temperature is 70° F.

446 - 1. Resistance of the window units.
2. a. 38.8 to 42.6 ohms.
   b. Approximately 218 volts.
   c. Approximately 304 volts.
3. You check it for cracks, bubbles, and discoloration. If any are found, check the TO to see if the condition is serious enough to justify replacement.

447 - 1. Install, bench check, repair, overhaul, and modify components.
2. TCTO.


LANDING GEAR CONTROL PANEL
WARN HORN SILENCER SWITCH
LANDING GEAR CONTROL SWITCH
UP
DN
UNLOAD SOLENOID
WARNING LIGHT PRESS-TO-TEST
WARN. LIGHTS
COPILOT'S INST PANEL
LG HIGH-TORQUE SWITCH
NORMAL
HI TORQUE
TWO-SPEED GEAR VALVE
UP
DOWN
LG SELECTOR VALVE
LH VALVE PANEL
LG CONTROL
LG HI-TORQUE
LG WARN. LIGHT
LG POS IND
ESSENTIAL DC BUS, 28-V
COPILOT'S LOWER CIRCUIT BREAKER PANEL
TOUCH DOWN RELAY
ISOLATED DC BUS, 28-V
PILOT'S SIDE CIRCUIT BREAKER PANEL
HORN SILENCER RELAY
SILENCER RELAY ENG NO. 1
SILENCER RELAY ENG NO 2
WARN HORN
SILENCER RELAY ENG NO. 4
SILENCER RELAY ENG. NO. 3
LH UNDER DECK RACK
THROTTLE NO. 1
THROTTLE NO. 2
THROTTLE NO. 3
THROTTLE NO. 4
EXTEND FLAPS
PEDESTAL
INDICATOR LIGHTS DIMMER NO. 1
75 Ω
200 Ω
PILOT'S INST PANEL LIGHTS
LH DISTRIBUTION PANEL
TOUCHDOWN RELAY
AUX TOUCHDOWN RELAY
DN
UP
RIGHT POS IND
NOSE POS IND
LEFT POS IND
COPILOT'S INST PANEL
UP
NOT UP
DN
NOT DN
ON GRD
IN AIR
MLG UP-POS IND SW
MLG DOWN-POS IND SW
TOUCHDOWN SW
LH MAIN WHEEL WELL
UP AND LOCKED
NOT UP AND LOCKED
NLG UP-POS IND SWITCH
DN
NOT DN
DN AND LKD
NOT DN AND LKD
NLG DOWN-POS IND SW
NLG DOWN-LOCK SW
NOSE WHEEL WELL
UP
NOT UP
DN
NOT DN
ON GRD
IN AIR
MLG UP-POS IND SWITCH
MLG DOWN-POS IND SW
TOUCHDOWN SWITCH
RH MAIN WHEEL WELL
42-1684

Foldout 1. Landing gear circuit.


59AR404 NOSE GEAR STEERING CONTROL BOX
(NOSE GEAR WHEELWELL)
59P404
1
2
3
4
5
6
7
A
M
B
E
S
Y
P
C
R
G
59P404
F
N
D
J
K
L
Q6 AND Q7
Q5
R17
LIM
R14
BALANCING RESISTOR
Q3 AND Q4
56VDC
42VDC
-24VDC
POWER SUPPLY
GRD
GRD -24VDC
CR4
AUTOMATIC CHECKING
K1
SCR FAILURE DETECTION
Q1 AND Q2
59P402
B
A
C
500Ω
2000Ω
59R402 FOLLOWUP POTENTIOMETER (ON NOSE GEAR STEERING POWER UNIT)
59VA4M61 CHECK VALVE (NOSE GEAR WHEELWELL)
59MA4M59 COMPENSATOR
59L403 SERVO VALVE
59P403
D
A
B
59RA4M60 ONE-WAY RESTRICTOR
ONE-WAY RESTRICTOR
ONE-WAY RESTRICTOR
BYPASS VALVE
59BU4M58 POWER UNIT (NOSE GEAR STRUT)
59FA4M65 FILTER (NOSE GEAR STRUT)
59P401
59R401 COMMAND POTENTIOMETER
FWD
59MA4M59 COMPENSATOR
59L403 SERVO VALVE
59P403
59P402
59R402 FOLLOWUP POTENTIOMETER
59FA4M65 FILTER
59RA4M60 ONE-WAY RESTRICTOR
42-1685

PIN E SUPPLIES POWER TO NOSE GEAR STEERING TEST SET

(CONTINUOUSLY CHECKS FOR OPEN OR SHORT IN NOSE GEAR STEERING SYSTEM. IF FAILURE OCCURS, SIGNAL IS SENT TO FAILURE DETECTION.)

(SIGNAL FROM AUTOMATIC CHECKING, FAILURE DETECTION SHORTS, DEENERGIZING K1.)

REFER TO UTILITY HYDRAULIC SYSTEM, T.O. 1F-4(R)C-2-6

COMPENSATOR MAINTAINS 300 PSI BACK PRESSURE TO PREVENT CAVITATION OF VANE MOTOR DURING DAMPING MODE

BYPASS VALVE SHUTTLES LEFT (ALLOWING POWER UNIT TO ACT AS SHIMMY DAMPER) WHEN SELECTOR VALVE IS DEENERGIZED.

Foldout 2. Nose wheel steering schematic

42350 03 S01 8306

CHANGE SUPPLEMENT

CDC 42350

AIRCRAFT ELECTRICAL SYSTEMS SPECIALIST

(AFSC 42350)

Volume 3

IMPORTANT: Make the corrections indicated in this supplement before beginning study of Volume 3. This supplement contains both "pen-and-ink" changes and additional pages. It is perforated and three-hole-punched so that you can tear out the additional pages and insert them in your volume. You are not required to post any changes listed in this supplement which correct typographical errors, unless such errors change or otherwise affect the meaning of the material.

Extension Course Institute

Air Training Command

CHANGES FOR THE TEXT

Pen-and-Ink Changes:

Page-Col	*Subject*	*Line(s)*	*Correction*
iii	Preface	2, 3 fr bot	Change "3350th Technical Training Wing" to "3330 Technical Training Wing."
4R		14	Change "The left main" to "All landing."
		24–25	Change "except the . . . and lock" to "remain down."
		28	Change "only in the left gear" to "common."
		31–32	Delete "and note . . . wheel well."
		1–8 fr bot	Delete "Now consider the . . . say the read-."
5L		1–11	Delete "ing is 28 . . . must be performed."
19R		7 fr bot	Change "wil" to "will."
33L		15	Change "light" to "lift."
77L		14 fr bot	Change "If" to "It."
78R		32	Change "swtich" to "switch."
88R		4 fr bot	Change "403" to "430."
90R	447-2		After answer 447-2 add new answers as follows: "448 - 1. A burned out light bulb. 448 - 2. No. The GTC starter relay gets its power across contacts of the energized start and ignition hold relay. 448 - 3. A defective 95-percent speed switch."

Page Changes:

Remove Pages	*Insert Pages*
	85a - 85c

448. Explain how to troubleshoot an auxiliary power unit.

Auxiliary Power Unit. The auxiliary power unit that we will deal with here is a model 85–71 gas turbine compressor (GTC). It is used on a typical cargo-type plane. The GTC is installed in a compartment just forward of the left main landing gear in the wheel well fairing. The compressor supplies air to pressurize the bleed air system when the plane is on the ground. The air can be used to start an engine or drive an air turbine motor (ATM). The ATM drives a generator which can furnish electrical power to the plane. The GTC also can be used to operate the plane's air conditioning system to provide hot or cold air as required.

Operation. Refer to figure 4-5 as we go through the operation of the GTC. With the plane on the ground, 28 VDC power from the GTC control circuit breaker is felt through the contacts of the GTC fire emergency handle. From there the power is applied across closed contacts in the auxiliary touchdown relay to a limit switch in the GTC door actuator (not shown in the schematic). With the GTC intake doors open, the power is felt across the limit switch to the GTC control switch on the anti-icing system control panel. To start the GTC, you turn the GTC control switch to the START position for a moment, then release the switch to the RUN position.

Let's take a look at what should happen when you start the GTC. When you put the control switch to the start position, several circuits are completed. Across the top pole of the control switch a circuit is made to turn on the start light, and a circuit also is completed, to energize the start and ignition hold relay. Note that this relay connects to ground through the 35 percent speed switch in the centrifugal switch assembly.

The bottom pole completes the circuits for the fuel control relay and the oil drain solenoid valve on the GTC. A circuit also is made to energize the GTC fuel relay in the cargo equipment rack.

The middle pole is used to complete circuits for the start counter, hourmeter, acceleration limiter coil, and the bleed shutoff and load control valve coil. The middle pole also provides power to the GTC starter relay in the left-hand distribution panel. With the starter relay energized, power is applied to the GTC starter motor and the GTC begins the starting cycle.

When you release the control switch to the RUN position, the middle pole provides a holding circuit for the start and ignition holding relay and the fuel control relay. The start light also is powered from the middle pole at this time.

As the starter motor is turning the GTC, oil pressure in the GTC starts to build up. At about 5,000 rpm, the oil pressure switch closes. This completes two circuits. The fuel shutoff solenoid valve is energized to allow fuel to be pumped into the combustion chamber. The ignition coil also is energized so that the igniter can ignite the fuel. The hot combustion gases and the starter drive the GTC until the GTC shaft speed reaches about 15,000 rpm. This is the 35 percent speed, and at this time the 35 percent speed switch opens to break the start and ignition holding relay circuit. This action will cause the starter to disengage. The igniter and the start light also de-energize at this time.

The GTC will continue to accelerate due to the hot combustion gases. At about 40,000 rpm, the 95 percent speed switch closes to complete a circuit to the on speed light and put power to the bleed air valve switch. The GTC will reach about 42,100 rpm. It is then governed to hold this 100 percent speed.

The GTC may be stopped manually by turning the control switch to OFF or by pulling the GTC fire emergency handle. When you do this, the fuel control relay will de-energize. This causes the fuel shutoff solenoid valve and the GTC fuel relay to de-energize and stops the flow of fuel to the GTC. The fire emergency handle should be used only for an emergency shutdown of the GTC. When the handle is pulled, the GTC oil supply is shut off.

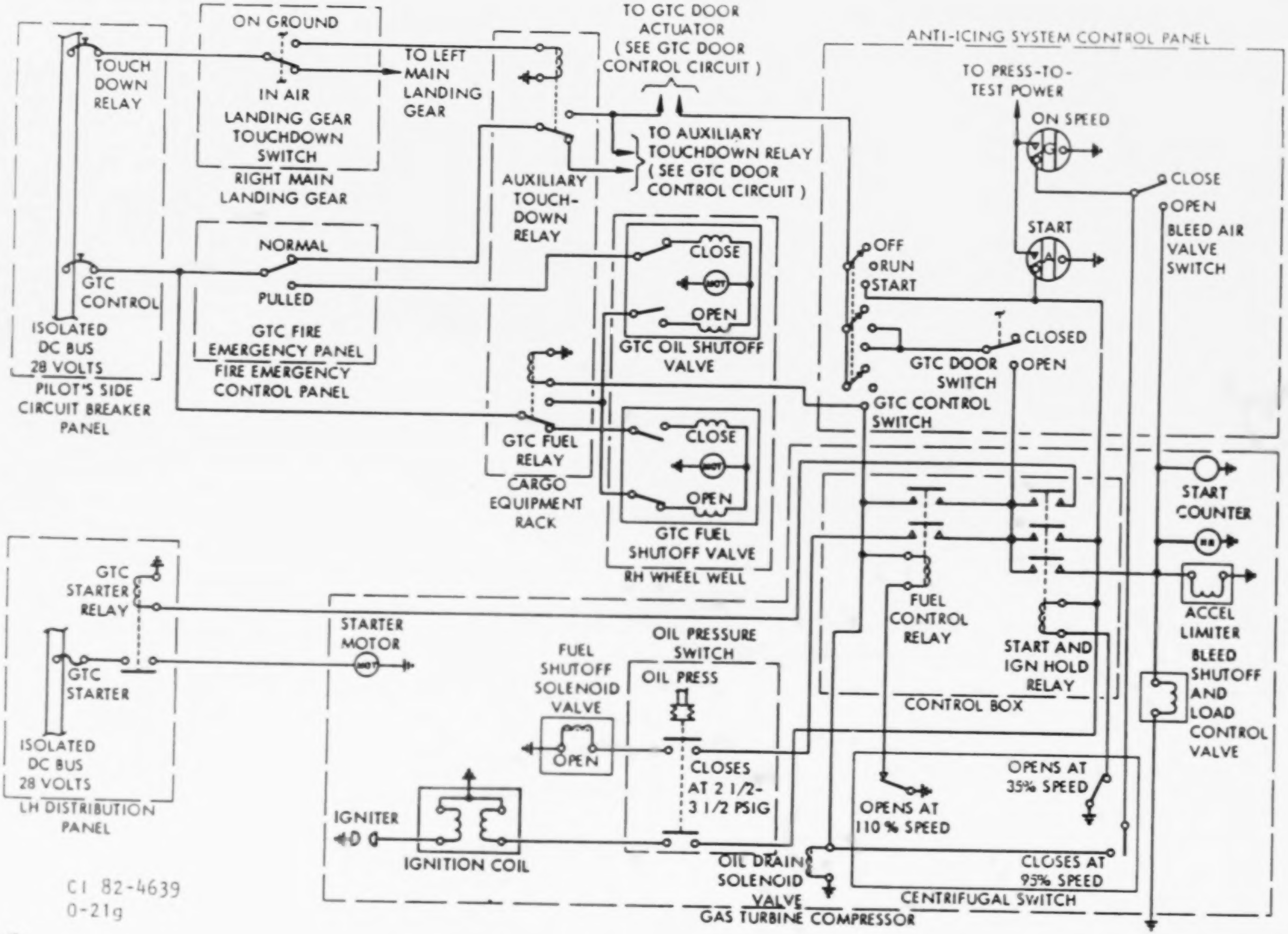
The GTC may be stopped automatically by the oil pressure switch or the 110 percent speed switch. The oil pressure switch opens the fuel shutoff solenoid valve circuit if oil pressure is lost while the GTC is operating. The 110 percent speed switch will open to de-energize the fuel control relay in case the GTC overspeeds.

Troubleshooting. In order to troubleshoot the GTC system, you must understand how it operates and use the proper tech data. You also may require assistance from the engine shop if a problem is in the GTC unit. Let's look at some possible problems that could develop in this system. Assume that you go out on a job where the GTC will not start. With power on the isolated bus, you turn the GTC control switch to the START position. If the start light does not come on and the starter motor does not turn, you should realize the problem is between the bus and the switch. You could check the circuit breakers and the fire emergency handle very fast and easily. Another easy-to-check problem would be to see if the GTC intake doors are not opened. If these items look good, then you can use your meter to check for proper operation of the auxiliary touchdown relay and begin to isolate the malfunction from there. If you know that the GTC intake doors have been removed and replaced recently, you will probably check the door limit switch before checking the auxiliary touchdown relay.

What would you check if the GTC does not start but the start light came on and stays on when the control switch is placed in the START and RUN positions? If you go to the GTC starter fuse, you are right. If the fuse is alright, then you can check the starter relay for proper operation. If the starter relay coil is not getting power, there is probably a broken wire somewhere between the starter relay and the start and ignition hold relay in the GTC control box. It also is possible that the top contact of the start and ignition hold relay is defective. Remember always to use the proper wiring diagram when troubleshooting the GTC control or any other electrical circuit.

Exercises (448):

1. If the GTC starts and operates alright, but the start


TO GTC DOOR ACTUATOR (SEE GTC DOOR CONTROL CIRCUIT)
ANTI-ICING SYSTEM CONTROL PANEL
ON GROUND
TOUCH DOWN RELAY
IN AIR
TO LEFT MAIN LANDING GEAR
LANDING GEAR TOUCHDOWN SWITCH
RIGHT MAIN LANDING GEAR
TO AUXILIARY TOUCHDOWN RELAY (SEE GTC DOOR CONTROL CIRCUIT)
AUXILIARY TOUCH-DOWN RELAY
TO PRESS-TO-TEST POWER
ON SPEED
G
CLOSE
OPEN
BLEED AIR VALVE SWITCH
START
A
NORMAL
PULLED
GTC CONTROL
ISOLATED DC BUS 28 VOLTS
PILOT'S SIDE CIRCUIT BREAKER PANEL
GTC FIRE EMERGENCY PANEL
FIRE EMERGENCY CONTROL PANEL
CLOSE
MOT
OPEN
GTC OIL SHUTOFF VALVE
OFF
RUN
START
CLOSED
GTC DOOR SWITCH
OPEN
GTC CONTROL SWITCH
GTC FUEL RELAY
CARGO EQUIPMENT RACK
CLOSE
MOT
OPEN
GTC FUEL SHUTOFF VALVE
RH WHEEL WELL
START COUNTER
ACCEL LIMITER
FUEL CONTROL RELAY
START AND IGN HOLD RELAY
CONTROL BOX
BLEED SHUTOFF AND LOAD CONTROL VALVE
GTC STARTER RELAY
STARTER MOTOR
MOT
GTC STARTER
ISOLATED DC BUS 28 VOLTS
LH DISTRIBUTION PANEL
FUEL SHUTOFF SOLENOID VALVE
OPEN
OIL PRESSURE SWITCH
OIL PRESS
CLOSES AT 2 1/2-3 1/2 PSIG
OPENS AT 110% SPEED
OPENS AT 35% SPEED
CLOSES AT 95% SPEED
CENTRIFUGAL SWITCH
IGNITER
IGNITION COIL
OIL DRAIN SOLENOID VALVE
GAS TURBINE COMPRESSOR

1

85b

C1 82-4639
0-21g

Figure 4–5. Gas turbine compressor schematic.

light does not come on, what is the probable malfunction?

2. If the start and ignition hold relay is defective, could you start the GTC up to 5 percent speed? Explain.

3. What problem is indicated if the on speed light does not come on when the GTC is operating normally and the light bulb is good?